Thompson Meadow Restoration Project

Hydrology and Soils Report

Plumas National Forest Service

Beckwourth Ranger District

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Introduction

This assessment evaluates direct and indirect effects of the Thompson Meadow Restoration and Water Budget Evaluation Project proposed action and the cumulative effect of past, present and future actions on the soil resource and water quality resources and watershed condition. Watershed condition includes the movement, timing and quality of water on the landscape (hydrology) and the condition of the soils. Standard soil and water quality mitigation measures are described, which apply to the Proposed Action alternative.

The Proposed Action would elevate the water table within the meadow portion of the project area, thus restoring the channel/floodplain hydrology which supported native wet/moist/mesic vegetation communities. In the current condition with a degraded channel, xeric plant communities are replacing predegradational communities, and soil erosion is occurring at an accelerated rate. Various meadow restoration treatment techniques are proposed for the project area. Actions include mechanized treatment of incised channels and re-vegetation. Anciallary activities include NFS road improvement and barbed wire fence building.

The Proposed Action would eliminate gully expansion as the primary source of soil erosion in the project area. It would also reduce wind erosion on bare areas on the meadow surface, but may increase erosion from surface run-off until the vegetative community responds (one to three years). As a result of the Proposed Action, the existing access road to the meadow will be improved and rolling dips built that will eliminate the current road surface rill erosion. Under the Proposed Action, the rate of soil erosion would be reduced and the depositional function of the floodplain would be restored. The No Action alternative would maintain the existing rate of erosion mentioned above. Porosity, organic matter and nutrients are expected to stay the same under the No Action Alternative. Soil porosity is likely to improve under the Proposed Action due to reinvigorated capillary action from the increased vegetation vigor; organic matter and nutrients are expected to approximately double, based on monitoring from similar projects (source?). Soil moisture regime is expected to improve under the Proposed Action by raising groundwater levels and groundwater being retained in meadow soils later into the growing season. The watershed above the project area comprises the cumulative effects analysis area for soils, which is well below the threshold of concern for susceptibility to cumulative watershed effects. Past timber management actions have not led to excessive erosion in the cumulative effects analysis area. The cumulative effects of on-going cattle grazing may affect soil parameters; however, this effect is likely to be diminished under the Proposed Action due to improved vegetative vigor and adaptive grazing management. Meadow vegetation productivity is likely to continue a slow decline under the No Action alternative.

By eliminating the incised channel, the Proposed Action allows for the floodplain and channel to regain hydrologic connectivity. The groundwater table is expected to remain closer to the meadow surface longer into the dry summer season, providing moisture at a depth that supports wet meadow and wetland plant communities. Raising the channel bottom depth to meadow elevation allows spring snow meltoff flows to overbank, spread across the floodplain, and infiltrate the meadow soils and become groundwater to support vegetation and contribute to late season stream flow (baseflow). The cooler groundwater seepage into the stream, combined with increased shade from riparian vegetation such as willow, are expected to reduce stream temperature. Under the No Action alternative, the floodplain would remain hydrologically disconnected from the stream channel, resulting in more rapid discharge of surface and groundwater from the meadow, and a continuing trend toward more xeric meadow vegetation.

The geographic context related to watershed condition for the Thompson Meadow Project includes climate and geology. The project area lies in the Northern Sierra Nevada Mountains and ranges from 5460 feet to near 5650 feet in elevation. Annual precipitation ranges from 11 to 32 inches (Feather River Coordinated Resource Management, 2013). Most of this precipitation falls in the winter as a mix of rain and snow. The topography is generally defined by relatively gentle plateaus, broad valleys, and some steeper drop offs and small but steep drainages. Mapped soil types within the project area are Keddie loam (26), Ramelli silty clay loam (34), Franktown-Fopiano families complex (170), Franktown family-Rubble land complex (173), Franktown-Sattley families complex (174), Haypress family (186) and Haypress-Toiyabe families complex (193). The Keddie loam soil type, which dominates the meadow area, exhibits moderate to moderately-high erosion potential. The upland soils are primarily comprised of the Haypress-Toiyabe families complex and exhibit high erosion potential.

Relevant Laws, Regulations, and Policy

Regulatory Framework

National Forest Management Act (NFMA) of 1976

This act amended The Forest and Rangeland Renewable Resources Planning Act of 1974. As described in Forest Service Manual Chapter 2550 (USDA, 2010), this authority requires the maintenance of productivity and protection of the land and, where appropriate, the improvement of the quality of soil and water resources. NFMA specifies that substantial and permanent impairment of productivity must be avoided.

Plumas National Forest Land and Resource Management Plan (LRMP)

Forest Plan standards and guidelines, as amended by the Sierra Nevada Forest Plan Amendment (SNFPA) Record of Decision (ROD), provide the relevant substantive standards to comply with the 1976 NFMA. The 1988 LRMP (USDA, 1988) establishes standards and guidelines for protection and maintenance of Forest watersheds, water quality, water supply, and soil productivity including:

- Implementation of Best Management Practices (BMPs) to meet water quality objectives and maintain and improve the quality of surface water on the Forest.
- Establishment of Streamside Management Zones (SMZs) per guidelines in Appendix M of the LRMP. These guidelines were mostly replaced by the recommendations for Riparian Conservation Areas (RCAs) described in the Sierra Nevada Forest Plan Amendment Record of Decision (SNFPA ROD).
- During project activities, minimize excessive loss of organic matter and limit soil disturbance according to Erosion Hazard Rating (EHR): for low to moderate EHR, conduct normal activities; for high EHR, minimize or modify use of soil disturbing activities; for very high EHR, severely limit soil-disturbing activities.
- Determine adequate ground cover for disturbed sites during project planning on a case-by-case basis. Suggested levels of minimum effective cover are: for low EHR, 40 percent; for moderate EHR, 50 percent; for high EHR, 60 percent; and for very high EHR, 70 percent. These suggested levels are adopted as the LRMP ground cover standards for the Thompson Meadow Project.

Management Area

The project area is within the Dotta Management Area (36) of the LRMP (USDA, 1988). General direction in this Management Area includes expanding range productivity, improving streams in deteriorating condition, and improving water quality. One specific standard for soil and water resource management is specified in these sections of the LRMP relating to maintaining and/or improving water quality: "In cooperation with CDFW, NRCS, and private landowners, stabilize the stream channels of the Red Clover Creek Watershed."

Sierra Nevada Forest Plan Amendment Record of Decision

The SNFPA ROD specifies Riparian Conservation Objectives (RCOs) for management activities within RCAs; a discussion of compliance with RCOs for the Thompson Meadow Project is presented in the Environmental Assessment. The SNFPA ROD also includes a standard and guideline for large down wood and snags:

- Determine retention levels of large down woody material on an individual project basis. Within westside vegetation types, generally retain an average over the treatment unit of 10-15 tons of large wood per acre. Within eastside vegetation types, generally retain an average of three large down logs per acre. For the Thompson Meadow project, the retention level of large down woody material will be 2-3 down logs of the largest down wood available per acre where borrow material is removed.

National Forest Service Manual for Soil Management

Forest Service Manual 2550 (USDA 2010) establishes the management framework for sustaining soil quality and hydrologic function while providing goods and services outlined in Forest land and resource management plans. Primary objectives of this framework are to inform managers of the effects of land management activities on soil quality and to determine if adjustments to activities and practices are necessary to sustain and restore soil quality. Soil quality analysis and monitoring processes are to be used to determine if soil quality conditions and objectives have been achieved. Soil management standards and guidelines are not applied to administrative sites or dedicated use areas such as roads and campgrounds.

Region Five National FSM Supplement for Soil Management

Region 5 FSM 2500 Chapter 2550 Supplement (USDA 2017) establishes three soil functions to be used for assessment and analysis to determine if the national soil quality objectives are being met: Support for Plant Growth Function, Soil Hydrologic Function, and Filtering - Buffering Function.

Federal Law

Clean Water Act of 1948 (as amended in 1972 and 1987)

The Clean Water Act establishes as federal policy the control of both point and non-point source pollution and assigns to the states the primary responsibility for control of water pollution. In response to this law, the Forest Service has developed BMPs in coordination with the State of California Water Quality Resources Control Board, with BMPs certified by the United States Environmental Protection Agency (USEPA).

Non-point source pollution on Plumas National Forest (PNF) has been managed for the past 19 years through the water quality management program contained in *Water Quality Management for Forest System Lands in California* (USDA, 2000). The BMPs contained in that document have recently been improved and replaced by a national Forest Service BMP manual, *National Best Management Practices for Water Quality Management on National Forest System Lands* (USDA, 2012). The 2000 California Water Quality Management Manual contains the 1981 Management Agency Agreement (MAA) between the California State Water Resources Control Board (CSWRCB) and the USDA, Forest Service. The State Board has designated the Forest Service as the management agency for all activities on National Forest lands and the MAA constitutes the basis of regional waivers for non-point source pollution.

Section 303(d) of the Clean Water Act

This section requires the identification of water bodies that do not meet, or are not expected to meet, water quality standards or are considered impaired. The list of affected water bodies, and associated pollutants or stressors, is provided by the CSWRCB and approved by the USEPA. The most current list available is the 2014 and 2016 303(d) list (CSWRCB, 2018). No water bodies on this list are located within the Thompson Meadow Project area. The nearest downstream water body on the 303(d) list is the North Fork Feather River between Lake Almanor and Lake Oroville. The Red Clover Creek HUC 5 watershed (#1802012203) generally flows northwestward toward its confluence with Last Chance Creek (HUC5#1802012202) and continues to drain into the Lower Indian Creek HUC5 watershed (#1802012204) and eventually into the Lower East Branch North Fork Feather River HUC 5 watershed (#1802012208) before entering the 303(d) listed reach in the Bucks-Grizzly HUC5 watershed (#1802012107). The North Fork Feather River is included on the 2010 303(d) list for PCBs, mercury and water temperature impairments. The Thompson Meadow Project is not expected to impact water temperature, nor legacy deposits or concentrations of mercury or PCBs in the North Fork Feather River. The 303(d) list describes hydropower modifications, flow regulation and modification as the potential sources for water temperature impairments.

State and Local Law

Regional Water Quality Control Board Requirements

Beneficial Uses identified by the CA Water Resource Control Board (Central Valley Region)

Beneficial uses are defined under California State law in order to protect against degradation of water resources and to meet state water quality objectives. The Forest Service is required to protect and enhance existing and potential beneficial uses (CVRWQCB, 1998). Beneficial uses of surface water bodies that may be affected by activities on the Forest are listed in Chapter 2 of the Central Valley Region's Water Quality Control Plan (commonly referred to as the "Basin Plan") for the Sacramento and San Joaquin River basins (SWRCB, 1998; as amended in 2018), and are described below for the Thompson Meadow Project area. The project area drains to the North Fork Feather River, for which existing beneficial uses include municipal and domestic water supply, hydropower generation, recreation, freshwater habitat, habitat suitable for fish reproduction and early development, and wildlife habitat.

Permitting Requirements

Compliance with Section 404 of the Clean Water Act would be assured per the preconstruction notification process required by the US Army Corps of Engineers for nationwide permit 27 (Aquatic Habitat Restoration, Establishment, and Enhancement Activities). A Section 401 Water Quality Certification from the State of California Central Valley Regional Water Quality Control Board would be secured prior to construction. A California Department of Fish and Game permit for lake and streambed alteration will be secured prior to construction since the project could potentially be implemented with State funds. A water right application for this project will not be made to the State of California because streambed restoration is not an appropriative use of water and this streambed restoration project is not diverting or storing water for a designated beneficial use (source? The 2011 letter from SWRCB Division of Water Rights).

Effects Analysis Methodology

Regulations for implementing the National Environmental Policy Act (NEPA) are found in the Code of Federal Regulations (40 CFR 1500-1508) and for the California Environmental Policy Act (CEQA) (California

Code of Regulations, in Chapter 3 of Title 14). These regulations require that analysis shall be presented of a proposed action's direct, indirect and cumulative effects. Direct effects are defined as those effects which are caused by the project action and occur at the same time and place as the action. Indirect effects are caused by the action and are later in time or farther removed in distance. Cumulative effect is defined as the impact which results from the incremental impact of the project action when added to other past, present and reasonably foreseeable future actions.

Geographic Analysis Areas

Watershed and Soil Analysis Areas

The geographic region defining the watershed analysis is a sub-watershed that falls within the boundaries of the Lower Red Clover Creek HUC 12 (180201220103) watershed. For soil and watershed resources, the 66-acre project area is within a 1783-acre (2.8 sq mi) cumulative effects analysis area (CWE). The cumulative effects geographic boundary is based on the watershed boundary above the project area, and is shown in Figure 1.

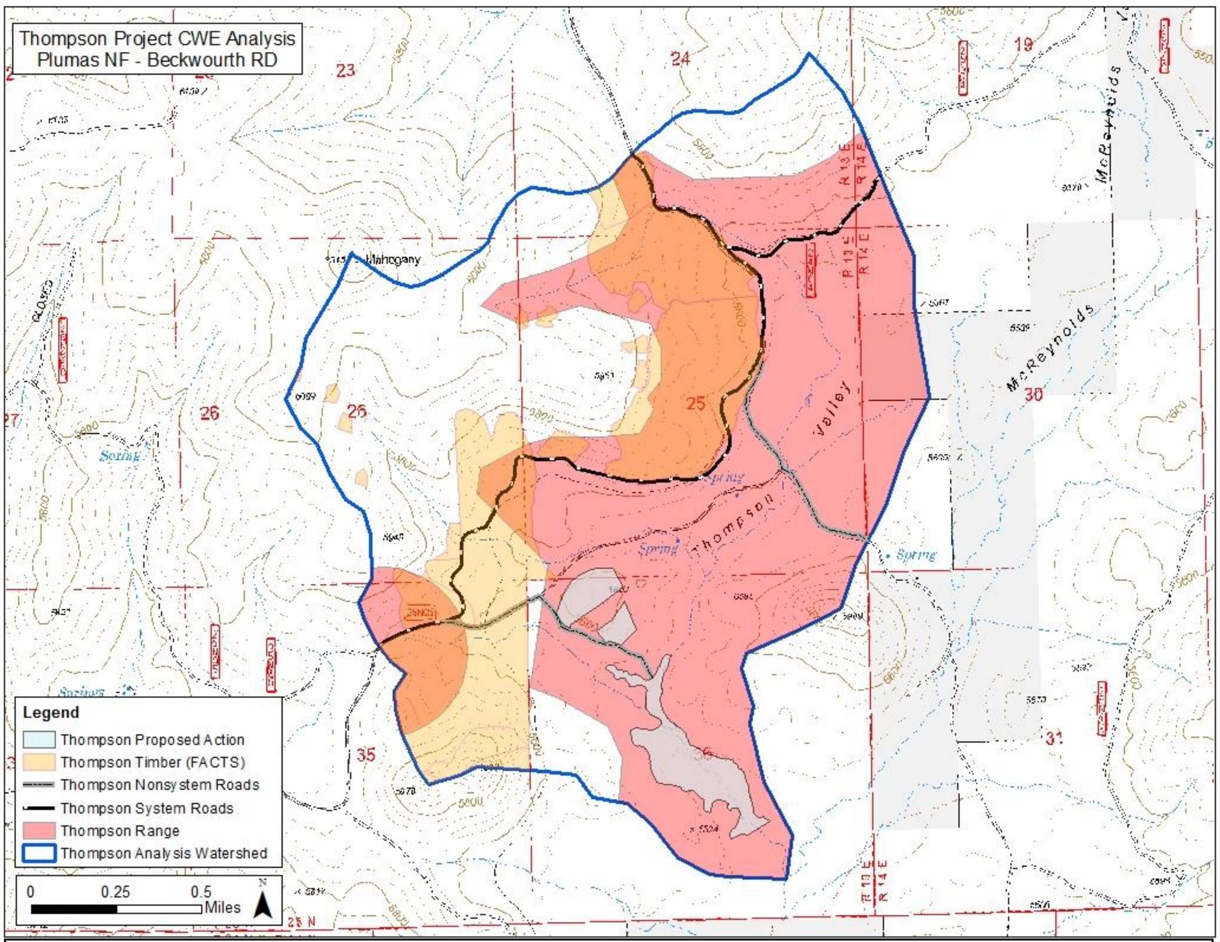

Figure 1. Cumulative effects analysis area

The spatial boundaries for analyzing the cumulative effects to watershed resources should be sized between 2,000 and 5,000 acres to determine risks of detrimental effects (USDA, 1988b). If too large of an area is chosen, effects due to the project may be too hard to separate from other activities in the watershed. If too small of an area is examined, there is a risk that one problem site would be considered detrimental when there is no connection to downstream conditions.

The time frame of the cumulative effects analysis includes the past in which actions have occurred that may affect the Thompson Meadow project area. The current condition of any watershed is the result of the cumulative effects of past land uses. In the project area, roads, railroads, and grazing have had substantial effects on watershed conditions since the mid-1800's, and currently contribute to the existing condition of the analysis area. Only the most recent actions (30 years) with a potentially measureable impact on the existing condition are discussed in detail. Potential future projects are derived from the District's schedule of proposed actions (SOPA). With these boundaries in mind, the past, present, and reasonably foreseeable future actions that may affect the cumulative effects analysis area are listed in Table 1.

The temporal boundaries for analyzing the cumulative effects are 30 years, because work done to develop the Region 5 methodology (USDA, 1988b) showed this to be an appropriate time scale. Often upland areas can recover from mechanical logging and wildfire on a scale of three to five years, but effects may linger longer in the stream channel systems. Poorly designed road systems and direct manipulation of channels such as placer mining may have much longer term effects.

Table 1. Cumulative effects activities

Past Actions – Vegetation Management		
Year	**Activity**	**Acres Treated**
2010	Red Clover Project - Fuels reduction work in the upland borrow areas	180
Past Actions – Erosion Control		
1987	Rock Structures in Thompson Creek	5
Present Actions		
Ongoing	Livestock grazing	74% of cumulative watershed effects analysis area = 1,783 acres
Reasonably Foreseeable Future Actions		
2021	Mapes Project	To Be Determined

Direct and indirect effects to water resources typically are confined to the immediate vicinity of the proposed activities with a slight chance of sediment from erosion moving downstream from these sites. Direct, indirect, and cumulative effects to soil resources would only affect areas where actions are proposed, so the Proposed Action project area defines the soil analysis area. Given adequate precipitation negative direct and indirect effects for water and soil resources are usually evident soon after implementation, then during and after the first winter runoff season. This is why implementation monitoring of BMPs occurs during or immediately after implementation of actions and effectiveness monitoring occurs after the first winter.

Analysis Methodology

Hydrology / Water Quality

The primary threat to functional hydrology and water quality in Sierra Nevada montane meadows is the presence of incised or gullied stream channels and a loss of connectivity to the natural floodplain. Additionally, channel incision leads to steeper groundwater flow gradients which leads to more rapid groundwater discharge into stream flows and a lowered groundwater table. These actively eroding channels result in widespread soil loss, reduced water availability, and decreases in productivity and biodiversity (American Rivers, 2016).

The following five indicators will be used to evaluate water quality and hydrology for this analysis: sedimentation, water temperature, groundwater elevation, stream flow, floodplain function, and ERA (for cumulative effects only).

- Sedimentation – This indicator measures the deposition of particles carried in stream flow. Because sediment transport is difficult and costly to measure, estimates of bank stability and erosion rates can be used as a proxy to evaluate sedimentation (American Rivers, 2012). Meadows with functional floodplains are sinks for sediment, while degraded meadows are a major source of sediment and turbidity to streams, potentially having negative impacts on water quality, fish habitat, and downstream water conveyance systems.

- Water temperature – Water temperature has direct and indirect effects on nearly all aspects of stream ecology. The amount of dissolved oxygen available to aquatic organisms in streams is partially dependent on water temperature. Temperature influences the rate of photosynthesis by alga and aquatic plants. Some environmental factors affecting stream temperature are groundwater inputs, channel and pool depths, riparian shade cover, and source of surface flow.

- Groundwater retention – The groundwater table is the elevation at which the ground becomes saturated, or filled to maximum capacity, with water. In uneroded meadows, groundwater tables are generally fully recharged by rain and snowmelt during the winter and spring, fall to maximum depths below meadow surfaces by August or September, and then begin to recover as evapotranspiration decreases and groundwater inflow continues (Wood 1975, USDA 2015, Loheide 2007). Overbank flooding is an important contributor to groundwater recharge in some meadows (Hammersmark 2018, Tague 2008, Ohara 2013) but meadows may also be saturated by groundwater flowing from surrounding bedrock aquifers (Essaid 2014). Meadows with eroded incised channels (“gullies”) lose their ability to retain groundwater due to increased local hydraulic gradients that temporarily increase groundwater discharge from meadow aquifers to eroded channels (USDA 2015, Loheide 2007). This effect of the incision draining the water table during summer months is more pronounced for deeper incisions (Essaid 2014). The water table drops most noticeably in the meadow area adjacent to incised channels (Essaid 2014). The level and duration of the groundwater table in meadows has a direct impact on plant communities and stream water temperature.

- Stream flow – Stream flow through a healthy meadow can be perennial (year-round), intermittent (seasonal) or ephemeral (carries water only during and immediately after precepitation events). Stream flow is a balance between inputs of precipitation, snowmelt, groundwater discharge, and evapotranspiration. Mountain meadows in the western United States are generally locations of groundwater discharge to streams (Essaid 2014). Baseflow is a term used in hydrology to describe stream flows that exist in a channel after tributary stream flows due to snowmelt have ceased. Thus, baseflow is the level of stream flow that exists due to a stream channel’s interaction (either positive or negative) with groundwater sources (Hoffman 2013). Incised channels in meadows typically result in more groundwater discharge to the stream causing an increase in streamflow during the dry season and a decrease in groundwater storage (USDA 2015, Essaid 2014). Restoration in some montane meadows has resulted in increased summer baseflows near the downstream end of the meadow (Hunt 2018, Hammersmark 2008).

- Floodplain function/connectivity – Restoration of floodplain connectivity allows spring snowmelt flows to overbank, spread across the floodplain, and infiltrate the meadow soils and become groundwater to support vegetation and contribute to late season stream flow (baseflow). Spreading flood flows across the floodplain also reduces flow stress within the stream channel, reducing channel erosion.

Soils

Three soil functions and their associated indicators will be used for assessment and analysis to determine if the USFS national soil quality objectives are being met: Support for Plant Growth Function; Soil Hydrologic Function; and Filtering - Buffering Function. Support for Plant Growth indicators include soil stability, soil strength, surface organic matter, soil organic matter, and soil moisture regime. Soil Hydrologic Function indicators include soil stability, soil structure and macroporosity. Soil Filtering and Buffering capacity is the soil's ability to act as a filter and buffer to protect the quality of water and air from the degrading effects of chemicals or excessive nutrients. Below are descriptions of each of the indicators:

- Soil stability - Effective soil cover is used as the measure to assess soil stability. An adequate level of soil cover is needed to prevent accelerated erosion. Without effective soil cover, an intense storm can generate large quantities of sediment from hill-slopes (Cawley, 1990). This measure consists of low-growing vegetation (grasses, forbs and prostrate shrubs), plant and tree litter (fine organic matter), surface rock fragments, and may also include applied mulches (straw or wood chips). Vegetative cover mitigates accelerated soil erosion by dissipating the energy of falling raindrops through interception and reducing surface water flows on meadow floodplains. For live vegetation, root structures enhance soil stability by holding soils in place. Existing effective soil cover was determined by qualitative ocular field assessment.
- Soil strength - Soil porosity and compaction is used as the measure to assess soil strength. Soil porosity is the volume of pores in a soil that can be occupied by air, gas, or water and varies depending on the size and distribution of the particles and their arrangement with respect to each other. Soil compaction increases the bulk density and decreases the porosity of soils. Compaction can slow plant growth and impede root development. Soil compaction restricts percolation and can cause poor water infiltration, potentially resulting in increased overland flow during high precipitation events and can cause plant nutrients to be relatively immobile or inaccessible (Poff, 1996). Compaction increases soil strength, potentially causing vegetation to use more energy to access nutrients and water, resulting in a decline of above ground plant growth. The degree and extent of susceptibility to compaction is primarily influenced by soil texture, soil moisture, coarse fragments, depth of surface organic matter, ground pressure weight of equipment, and whether the load is applied in a static or dynamic fashion. Research suggests that the effect of severe compaction on biomass productivity is highly dependent upon soil texture (Powers et al., 2005). Soil compaction can also affect soil hydrologic function by inhibiting infiltration, thus increasing surface runoff.
- Soil organic matter – Soil displacement or disturbance can reduce or eliminate soil organic matter locally and decrease availability of soil organic matter nutrients to roots of desired vegetation. Soil organic matter is the primary source of plant-available nitrogen, phosphorous, and sulfur; provides habitat for the diverse soil biota that carry out energy transformation and nutrient cycles; contributes to soil structure and porosity of soils; protects soils from erosion; and enhances

infiltration and hydrologic function (Neary et al., 1999). The amount of organic matter within the mineral soil is indicated by the color and thickness of soil in the upper horizon. Surface organic matter consists of living biomass (plant roots, microorganisms, invertebrates, and vertebrate fauna) and dead biomass (bark, large woody debris, litter, duff, and humus materials).

- Soil moisture regime – Soil moisture is dependent on several factors such as depth to water table, soil type, quantity and timing of surface water inputs and a soil's ability to hold water and release it slowly through the dry months. Soil moisture spatial and temporal distribution dictates the spatial extent, plant species diversity, and plant vigor of an area. Soil buffering capacity –
- Soil Buffering capacity will not be analyzed for this project since no chemicals are being proposed for use.

Cumulative Effects

A cumulative impact, as defined in 40 CFR 1508.7, is: the impact on the environment which results from the incremental impact of the action when added to other past, present, and foreseeable future actions regardless of what agency (Federal or non-federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (CEQ, 1971).

Cumulative impacts may occur off-site and, in the case of the water resource, may affect downstream beneficial uses of water. Effects can be either beneficial or adverse and result from the synergistic or additive effects of multiple management activities within a watershed (USDA, 1988b). Cumulative watershed effects (CWE) analyses have traditionally focused on impacts to downstream beneficial uses. These include aquatic habitat, hydroelectric power generation, and domestic water supplies. Near-stream disturbances, when compared with upslope disturbances, are more likely to cause site-specific biological effects, as well as downstream physical effects (Menning, 1996) (McGurk & Fong, 1995).

There are numerous methods for assessing the effects of land use activities on the landscape. A discussion and comparison of different methodologies can be found in documents such as, *A Scientific Basis for the Prediction of Cumulative Watershed Effects* (Dunn et al., 2001) and *Cumulative Watershed Effects: Applicability of Available Methodologies to the Sierra Nevada* (Berg et al., 1996). For the purpose of this CWE analysis, the effects of past, present, and reasonably foreseeable future actions were assessed using the Region 5 Cumulative Off-site Effects Analysis (USDA, 1988b). An equivalent roaded acre (ERA) is a conceptual unit of measure used to assess ground-disturbing activities and track general changes in the hydrologic functioning of watersheds. Alterations in watershed hydrology are believed to be the most probable mechanism for initiating adverse cumulative watershed effects on aquatic habitat and beneficial uses. Numeric disturbance coefficients are used to convert acres of past management activities such as timber harvest, underburning, and grazing to ERAs by comparing the effect of these activities to that of a road in terms of altering surface runoff patterns and timing. For example, one acre of underburning, a management activity that has a disturbance coefficient of 0.05, is equal to 0.05 ERA. A linear recovery curve is used in the ERA model and reflects the landscape's ability to recover from land management associated disturbances (Figure 2).

For the project CWE analysis watershed, disturbances were calculated with Geographic Information System (GIS) programs, using standard National Forest corporate data files such as the NFS road network, grazing allotment boundaries, and the Forest Activity Tracking System (FACTS), which spatially records past vegetation management actions. Disturbances are added together to determine a cumulative ERA value for that watershed. Dividing the total ERA by the size of the watershed yields the percent of the watershed in a hypothetically roaded condition. This value can serve as an index to describe impacts to downstream water quality. An increase in ERA for a watershed indicates increased concentration of surface runoff, which could result in detrimental changes to sedimentation rates and stream channel condition that could subsequently have effects on downstream water quality and beneficial uses.

Watersheds and their associated stream systems can tolerate some level of land disturbance, but there is a point at which land disturbances begin to substantially impact downstream channel stability and water quality. This upper estimate of watershed tolerance to land disturbance is called the threshold of concern (TOC). As ERA levels approach the TOC (total ERA divided by the watershed area), there is an increased loss of soil porosity and soil cover, resulting in greater runoff potential and peak flows. When the total ERA in a watershed exceeds the TOC, susceptibility for significant adverse cumulative effects is high. For example, water quality may be degraded to the point where the water is no longer available for established beneficial uses, such as municipal water supplies or no longer provides adequate habitat for fisheries. In addition, stream channels can deteriorate to the extent that riparian and meadowland areas become severely degraded.

Natural watershed sensitivity is an estimate of a watershed's natural ability to absorb land use impacts without increasing the effects of cumulative impacts to unacceptably high levels (USDA 1988b). Watersheds with a high natural sensitivity can tolerate less land disturbance and require greater care when planning land use activities than watersheds with a low sensitivity. Watershed sensitivities calculated for the Herger-Feinstein Quincy Library Group Forest Recovery Act (USDA, 1999) were used to inform the CWE analysis for this project. Variables considered for that HFQLG watershed sensitivity analysis included soil erosion hazard rating, rain-on-snow potential, vegetation recovery potential, and the slope of the watersheds. Based upon the assessment of these measures within Thompson Meadow Restoration Project subwatersheds, as well as a review of land use history and resultant impacts to beneficial uses in similar watersheds, it was determined that TOC levels would be set at 12 percent ERA.

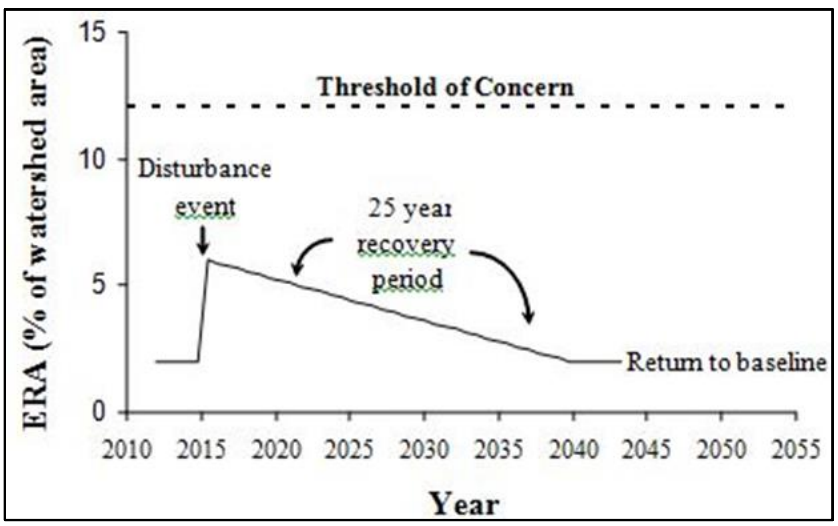

Figure 2. Conceptual disturbance and recovery model

Direct and Indirect Effects Indicators for the Thompson Meadow Restoration Project

Indicator Measure 1: Soil stability - effective soil cover

Indicator Measure 2: Soil porosity and compaction

Indicator Measure 3: Surface organic matter

Indicator Measure 4: Soil moisture regime

Indicator Measure 5: Sedimentation

Indicator Measure 6: Water temperature

Indicator Measure 7: Groundwater retention

Indicator Measure 8: Stream flow

Indicator Measure 9: Floodplain function

Short-term timeframe: From implementation to one year post treatment.

Long-term timeframe: Erosion problems that could occur following the first one to two winters after treatment could result in soil and hydrology issues that may persist for decades.

Cumulative Effects Analysis

Indicator Measure: Percent of watershed in equivalent roaded acre (ERA)

Long-term timeframe: 30 years

Spatial Boundary: Analysis sub-watershed

Methodology: Region 5 Cumulative Watershed Effects Model (described above)

Affected Environment

The 78,000-acre Red Clover Creek Hydrologic Unit Code (HUC) 5 watershed, located on the Beckwourth Ranger District, generally flows northwestward toward its confluence with Last Chance Creek and continues to drain into the Indian Creek HUC 5 watershed and eventually into the East Branch North Fork Feather River HUC 5 watershed. The eastern two-thirds of the Feather River watershed, including Red Clover watershed, occupy a geologic feature called the Diamond Mountains. While abutting the Sierra batholith, the Diamond Mountains are a separate amalgam of meta-volcanic, volcanic and meta-sedimentary formations with granitic intrusions intermixed by tectonic faulting (Durrell, 1988). The Diamond Mountains are much older than the Sierra Nevada. As a consequence, erosional processes coupled with faulting have resulted in long, extensive alluvial meadow features. Many of these meadows were once lakes as recently as the Pleistocene era.

The Diamond Mountains are also the transition between the moist, temperate west slopes of the Sierra Nevada and the arid Great Basin. The orographic crest of the Sierra Nevada range is approximately 35 air miles west of Red Clover Creek, resulting in a rain-shadow effect, which contributes to an average annual precipitation of 25-30 inches and 8 inches of run-off. The bulk of annual precipitation falls as snow from Pacific frontal systems during the winter (October-May) with a dry summer. Intense thunderstorms occur somewhere in the watershed during the summer every year, which can generate significant local erosional events (Cawley, 1990). Major watershed scale floods are the result of long duration, intense, rain-on-snow, storm events (1955, 1986, 1997, 2017). Drainage patterns in the watershed are defined by geology, including faults and fractures as well as soils and vegetation.

The nearly 70-acre project area is located at the bottom of a 1,783-acre watershed. Elevation in the watershed above the project area peaks at 6,345 feet. Along ridgetops and steep side slopes, boulders and rock outcrops dominate the landscape. Elevation within the project is 5,460 feet to 5,650 feet. Soil types range from clay to sandy loam in the valley bottom and alluvial fans with gradients between 0 and 4%. In a pre-degradation condition, these floodplain and fan soils were stable, anchored by wet or mesic vegetation complexes with deep, dense root systems and excellent infiltration. Streamflow in such a landscape is less “flashy”, only responsive to rainfall and snowmelt events once the soils are saturated.

For meadows in good condition, sediment and nutrients delivered from the upper watershed are filtered, stored, and ultimately incorporated into the meadow soils. The soil types along the road access and upland borrow areas range from cobbly loam to stony loamy sand.

Since 2012, streamflow through the meadow has been continuously measured (every 15 minutes) through the spring and summer months at three gages as part of DWR's monitoring and modeling effort. Gages are located on the main channel of Thompson Creek at both the top and bottom ends of the project area. The third gage is located on the west side tributary channel near the top of the project area. Flow rates are recorded annually for the period from April 1 through November 1. Flow through the summer months is very low, with the maximum daily flow rate for June 1 through September 30 at the downstream gage averaging 0.14 cubic feet per second (cfs) for 2016 (an above normal precipitation year). During these months, little increase in flow is recorded from the upstream mainstem gage to the downstream gage, with the 2016 data typically indicating a difference less than 0.03 cfs. The downstream gage was damaged by ice flows during the large floods of winter 2017 but data from the upstream gage indicate that the flow increase generated by that season's large snowpack had little effect on summer streamflow; from July 1 through September 30, the difference between the daily maximum flow rates recorded at the upstream gage in 2017 was identical or less than 0.03 cfs greater than the flowrates recorded in 2016.

Flood flows through the project area clearly recede by April 1 each year. The largest flow recorded at the downstream gage between April 1 and November 1 for 2014-2016 is 1.26 cfs (on April 22, 2016). For the design of the proposed project, the maximum 100-year flood flow is estimated to be approximately 275 cfs. These peak flows are expected to be of short duration, rising and falling sharply within 24 hours. For the purposes of DWR's study, the gages were designed to detect small changes in summer streamflow and are not capable of measuring large flood flows. However, images from a camera located on the main channel near the downstream end of the project indicate that the peak flood flow from January 2017 rose and fell sharply between the morning of January 8 and the morning of January 9 (Figure 3).

Summer streamflows in Red Clover Creek may have been higher in the 1960s and 1970s than in recent years, with climatic conditions likely being a large factor contributing to this difference. Hydrologic bulletins published by DWR documented year-round stream flow monitoring that occurred at Chase Bridge between 1964 and 1975 (DWR 1964-1975). While only in only one season during this monitoring period was the minimum flow reported to be zero (in 1970), USFS monitoring at this bridge observed zero surface flow in summer of 2012 (Hoffman 2013). This change can be clearly correlated, at least in part, to climatic changes. The period of DWR's monitoring appear to have had greater snowpack and annual precipitation that in recent years, particularly the four consecutive years of drought that occurred in California from 2012-2015. Snowpack measurements at DWR's nearby Abbey monitoring station demonstrate significantly lower snowpack measurements in recent years than during the 1964-1975 DWR monitoring period (See Table 2). For the 1963-1975 period, early April snow depth was measured to be less than the mean in 6 of the 13 events, a 46% occurrence rate that is reasonably expected for comparison with a mean value. However, for the following 29 years (1976-2004), April snow depth was below average in 21 events (72%) and zero snow depth was recorded for the three April events in 2013-2015, which did not occur in any of the other 53 years. Similarly, total annual precipitation recorded at a weather station in Quincy, California indicated below average precipitation in 6 annual seasons from 1963-1975, but 9 seasons of below average precipitation in the most recent 13 years (2006-2018). Similarly, Pacific Gas and Electric documented an estimated 23% reduction in average annual flow on East Branch North Fork Feather River for the 1976-2009 period, compared with the 1950-1975 period, with decreased snowpack cited as a likely cause (Freeman 2010).

Table 2. Early April Snowpack Depth (at ABY) and Total Annual Precipitation (at QYR) for nearby weather stations

Year	April Snowpack Depth (inches)[1]	Difference from Mean Snowpack Depth (inches)	Total Annual Precip (inches)[2]	Difference from Mean Annual Precip (inches)		Year	April Snowpack Depth (inches)[1]	Difference from Mean Snowpack Depth (inches)	Total Annual Precip (inches)[2]	Difference from Mean Annual Precip (inches)
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1963	13.5	-10.3	54.7	14.6		1993	36	12.2	44.5	4.4
1964	30.5	6.7	28.2	-11.9		1994	11	-12.8	18.1	-22.0
1965	27	3.2	54.0	13.9		1995	45.5	21.7	63.8	23.7
1966	16	-7.8	26.2	-13.9		1996	26	2.2	39.6	-0.5
1967	38	14.2	57.6	17.5		1997	14	-9.8	41.6	1.5
1968	18	-5.8	35.4	-4.7		1998	38	14.2	51.1	11.0
1969	57	33.2	57.0	16.9		1999	139	115.2	32.3	-7.8
1970	6	-17.8	51.7	11.6		2000	22	-1.8	43.0	2.9
1971	41	17.2	50.5	10.4		2001	11	-12.8	17.5	-22.6
1972	2	-21.8	29.7	-10.4		2002	20.5	-3.3	32.6	-7.5
1973	35.5	11.7	38.5	-1.7		2003	6.2	-17.6	54.5	14.4
1974	16.5	-7.3	67.4	27.3		2004	11.5	-12.3	32.9	-7.2
1975	63.5	39.7	35.2	-4.9		2005	32	8.2	38.1	-2.0
1976	1.5	-22.3	18.5	-21.6		2006	29.5	5.7	57.5	17.4
1977	12.5	-11.3	10.7	-29.4		2007	13	-10.8	26.1	-14.0
1978	22	-1.8	56.6	16.5		2008	27	3.2	25.6	-14.5
1979	22.5	-1.3	25.9	-14.2		2009	24	0.2	37.5	-2.6
1980	23.5	-0.3	42.6	2.5		2010	39.5	15.7	33.4	-6.7
1981	15	-8.8	33.0	-7.1		2011	62	38.2	58.7	18.6
1982	24.5	0.7	69.3	29.2		2012	16.5	-7.3	33.0	-7.1
1983	57	33.2	68.3	28.2		2013	0	-23.8	38.9	-1.2
1984	11	-12.8	47.8	7.7		2014	0	-23.8	23.4	-16.8
1985	25	1.2	27.9	-12.2		2015	0	-23.8	30.9	-9.2
1986	10	-13.8	52.6	12.5		2016	8	-15.8	51.6	11.5
1987	11.5	-12.3	20.8	-19.4		2017	31	7.2	80.9	40.8
1988	0	-23.8	24.6	-15.5		2018	22	-1.8	37.2	-2.9
1989	17	-6.8	41.3	1.2						
1990	8	-15.8	32.8	-7.3		**Mean**	23.8		40.1	
1991	22	-1.8	23.4	-16.7		**Median**	21.3		37.8	
1992	1.5	-22.3	17.5	-22.6						

1 - Snowpack depth from CDEC Station "ABY" near Bagley Pass (Sec 8, T24N, R13E)

2 - Total annual precipitation data from CDEC Station "QYR" near Quincy, CA

http://cdec.water.ca.gov/dynamicapp/QueryF?CWD

Figure 3: Remote camera photos taken within a 24-hour period show how quickly large floods rise and recede in the project area. Photo location is along Thompson Creek at the headcut near the downstream end of the proposed project. Photos were taken January 8-9, 2017 during a rain-on-snow event that produced a 20-year or more flood event. Photo date and time are labeled. Middle photo is at or near peak flood stage on the afternoon of January 8. Top photo is from 6 hours earlier on the morning of January 8. Bottom photo is from early the following morning, January 9.

Existing Condition

The existing conditions reflect the aggregate impact of prior human actions and natural events such as wildfire that have affected the environment and might contribute to cumulative effects. The current conditions in the analysis watershed has been impacted by many actions over the last century—specifically timber harvest, wildfire, livestock grazing, mining, and the transportation system associated with all these activities.

Existing Hydrologic Conditions and Water Quality

There is a need to prevent further degradation of the stream and meadow system along Thompson Creek in order to improve low flow and peak flow conditions, groundwater table depth and duration, and water quality by preventing further bank erosion and providing stable stream channel structure. Under existing conditions, the stream channel for Thompson Creek is incised within the historic (pre-1850) meadow (Wood, 1975) to a depth of 4 to 10 feet, with incised depths of more than 7 feet being most prevalent. This incision means that the stream channel has been cut off from its historic floodplain, particularly along the reaches that are incised over 7 feet. For these severely incised reaches, high energy flood flows are confined within the incision, causing vertical, highly eroded stream banks. This accelerated erosion during large floods has washed away willows, sedges, and other riparian vegetation that can stabilize stream banks and channel structure.

Under the existing condition, it is unlikely that any but the most extreme flood events would allow the channel to overflow onto the historic meadow. Therefore, much of the soil and bank-building sediment materials are transported through the degraded channel, rather than deposited onto the floodplain. Transport of sediments through the channel reduces water quality downstream because of in-channel sedimentation. In addition, shallow groundwater flows have been altered due to the incised channel and the lack of a fully developed floodplain.

Existing Soil Condition

There are 7 soil map units in the project area: Keddie loam, channeled, 2-4% slopes (map unit 26); Ramelli silty clay loam, 0-2% slopes (map unit 34); Franktown-Fopiano families complex, 15-45% slopes (map unit 170); Franktown family-Rubble land complex, 30-70% slopes (map unit 173); Franktown Sattley families complex, 10-50% slopes (map unit 174); Haypress family, 30-50% slopes (map unit 186); and the Haypress-Toiyabe Families Complex, 2-30% slopes (map unit 193) The Keddie loam and Ramelli silty clay loam are very deep, poorly drained soil alluvium derived from mixed parent materials. They are used for irrigated pasture and rangeland, with the caveat that the poor drainage provides a wetness which limits the variety of plant species that can grow there, as well as the period of grazing. Keddie loam is subject to occasional, brief flooding, and can form channels. Ramelli silty clay loam is subject to frequent flooding and can form channels. These two soil types are dominant in the meadow area of the proposed project. The incision of the stream channels over the last century has removed the influence of water from these soils, as well as the soil's influence over the hydrology.

The upland borrow areas and access road corridor are dominated by Haypress-Toiyabe families complex. The Haypress family soils are shallow, somewhat excessively drained soils derived from weathered granodiorite, while the Toiyabe family soils are excessively drained, shallow soils derived from weathered quartz-diorite. The remaining 4 soil types from the list above occur in small areas on the periphery of the Project area. The Franktown family are well-drained, shallow soils of welded tuff residium weathered from andesite. The Sattley family are well drained, shallow soils derived from basic volcanic breccia parent material, and the Haypress family is somewhat excessively drained soils of residium derived from granodiorite parent material. Table 3 lists soil characteristics from the Soil Resource Inventory, USDA, Plumas NF, 1988 and the USDA-NRCS WebSoil Survey (from which the above information was also derived).

Table 3: Soil Characteristics (USDA, 1988; NRCS WebSoilSurvey, 2018)

Soil map unit	Soil name	Acres	% of Project area	Flooding	Productivity	Erosion Hazard Rating *(EHR)	Management Concerns	Erosion Factor K*
26	Keddie loam	36.03	54.97	Occasional		Slight	Soils are subject to compaction; deep, poorly drained; minimize equipment footprint; re-veg all disturbed soil; time work for dry season	0.32
34	Ramelli clay	6.30	9.61	Frequent	2,000 – 4,500 pounds per acre	Slight	deep, poorly drained; re-veg all disturbed soil; time work for dry season	0.32
170	Franktown-Fopian families	1.64	2.50	None	<20 cuft/acre/yr 7	Moderate	Soils are subject to compaction;	0.05
173	Franktown family-Rubble land complex	0.71	1.08	None	<20 cuft/acre/yr 7	Not Rated	No data	No data
174	Franktown-Sattley families complex	1.21	1.85	None	<20 cuft/ac/yr (Franktown) 7 20 – 84 cuft/ac/yr (Sattley) 5-6	Moderate	Soils are subject to compaction; minimize equipment or soil disturbing activities; time work for dry season	0.05
186	Haypress family	1.99	3.04	None	20 – 49 cuft/ac/yr 6	Severe	Design improved road access with maximum drainage; erodibilty potential – minimize soil disturbing activities; time work for dry season	0.02
193	Haypress-Toiyabe families complex	17.66	29.95	None	20 – 49 cuft/ac/yr 6	Moderate	Design improved road access with maximum drainage	0.02

Table 4 shows a summary of soil indicators that were visually assessed to evaluate existing soil conditions. The indicator condition is rated as: Good (meets desired condition), Fair (partially meets desired condition), or Poor (does not meet desired condition).

Table 4. Existing soil condition

Soil Function	Indicator	Condition (good, fair, or poor)
Support for Plant Growth and Hydrologic Functions	Soil stability	*Upland borrow site* – Good. Slopes are less than 35% and effective soil cover is well above 70% and evenly distributed. *Access road* – Fair. Minor rill erosion on existing access road to meadow. *Meadow/stream channel* – Soil cover on the meadow is good, well above 70% and evenly distributed. Soil cover along the incised stream channel banks is poor. Gullied channel bisects meadow; strong evidence of active erosion on main channel and smaller tributary channels. Several eroding headcuts exist at the downstream end of the meadow where the tributary channels flow into the mainstem.
Support for Plant Growth Function	Surface organic matter (OM)	*Upland borrow site* – Good. Amount of organic matter is within the range suitable for soil type, ecological setting and fire return interval. *Meadow/stream channel* – Fair. Portions of the area are deficient in surface organic matter, particularly on steep, eroding, and non-vegetated channel banks.
Support for Plant Growth Function	Soil organic matter (SOM)	*Upland borrow site* – Good. Thickness and color of upper soil layer is consistent with soil type and ecological setting. *Meadow/stream channel* – Fair. Thickness and color of upper soil layer is not consistent with ecological setting and does not support expected plant species communities adequately.
Support for Plant Growth Function	Soil strength	*Upland borrow site* – Good. Soil strength supports desired plant communities and root depths. Soil compaction is similar to natural condition and not excessively impacted by previous motorized traffic, such as timber harvest equipment. *Meadow/stream channel* – Fair. Cattle trailing and infrequent vehicle access to meadow monitoring equipment has resulted in soil compaction that is minorly distributed throughout the meadow. Soil strength increased sufficiently to inhibit plant root growth in these areas.
Support for Plant Growth and Soil Hydrologic Functions	Soil structure & macroporosity	*Upland borrow site* – Good. Soil structure & macroporosity are relatively unchanged from natural condition. *Meadow/stream channel* – Fair. For minor portions of the area, erosion is evident and alters soil structure. Where the tributary channel flows onto the meadow, cattle trails may confine spring season runoff and prevent flows from distributing across the meadow surface. Vehicle tracks may also cause this effect but are generally located outside of tributary channel flow areas.

Environmental Consequences

Alternative A – Proposed Action

Direct and Indirect Effects

Soil stability/Effective soil cover, Proposed Action Direct Effects

The Proposed Action would result in creation of some areas of bare soil, particularly in the areas where partial channel fill plugs are constructed, where the complete channel fill is constructed, and in the hillside and meadow borrow areas. Topsoil excavated from the borrow sites would be stockpiled and then spread over the surface of the partial channel fill and the meadow and hillside borrow areas to facilitate quicker establishment of vegetation on the newly constructed surfaces. Existing dormant seed within the placed topsoil would provide substantial vegetative regrowth and soil cover, particularly for the channel fill and meadow borrow areas where the restored water table would reinvigorate meadow vegetative species. Additionally, filled surfaces and borrow areas would be seeded with locally collected native grass seed. Sedge mats would be excavated from the existing channel bottom and placed over much of the surface of the complete channel fill reach and along edges of partial channel fill plugs. Construction traffic across the meadow would cause bare vehicle tracks but would not remove topsoil so vegetative regrowth is expected. Hillside borrow areas would be tapered to match existing contours.

Soil stability/Effective soil cover, Proposed Action Indirect Effects

Significant vegetative regrowth within 1-3 years is expected on bare soil areas created by the Proposed Action, resulting in effective soil cover well in excess of 70% throughout the project area. This soil cover would support natural plant growth function and prevent any areas of accelerated soil erosion on the meadow or hillside borrow areas. Raising the water table in the meadow would result in riparian vegetation establishment on stream channel banks.

Soil stability/Effective soil cover, Proposed Action Cumulative Effects

Cumulative effects from past vegetation management in the analysis area have not significantly altered soil cover and future vegeation treatments would maintain the areal extent of soil cover in excess of 70% (USDA 2011). Cumulative effects from past and current livestock grazing have contributed to current conditions and are considered in the cumulative watershed effects analysis. On-going livestock grazing will continue to have a potential effect on soil cover, particularly where cattle trails form. However, such trailing would be dispersed across the meadow and would not significantly impact plant growth function. The proposed fence around channel restoration treatments would protect the regrowth of meadow and riparian vegetation that will provide adequate soil cover. SNFPA ROD standards and guidelines for grazing limit the amount of meadow forage that can be utilzed by grazing. The Proposed Action would result in improved vegetative vigor that can better withstand grazing pressure when grazed.

Soil porosity and compaction, Proposed Action Direct Effects

The Proposed Action would result in creation of some areas of soil compaction, particularly along the tracks of construction vehicles. Where necessary, these tracks would be scarified with construction equipment to restore soil infiltration. Excavation of hillside borrow areas would be implemented with tracked equipment to limit ground pressure and traffic would be dispersed across the hillsides. Hillside borrow areas would be tapered to match existing topographic contours and final constructed surfaces would have soil density similar to the adjacent natural conditions. Partial channel fill and complete channel fill embankments would be constructed with similar soil densities as adajacent meadow soils. With soil density essentially restored to levels of adjacent undisturbed soils, soil plant growth function and soil hydrologic function are not expected to be impacted by the Proposed Action.

Soil porosity and compaction, Proposed Action Indirect Effects

Establishment and reinvigoration of meadow and riparian vegetation, as described above for soil cover, would improve future soil infiltration in the restored meadow due to plant root activity. Similarly, regrowth on the hillside borrow areas would aid soil infiltration. Root activity due to vegetative regrowth on construction vehicle tracks in the meadow, aided by the restored water table, would further reduce soil compaction that occurred during construction.

Soil porosity and compaction, Proposed Action Cumulative Effects

Cumulative effects from past vegetation management in the analysis area have not significantly altered soil porosity and compaction within the project area. Few relic skid trails are evident in the proposed hillside borrow areas and, where present, were found to be well vegetated and have not significantly impacted soil plant growth function. These trails are well drained and have not altered runoff patterns to the point that soil hydrologic function has been impacted. Similarly, future timber harvest or fuel treatments in the project area are not expected to significantly impact soil porosity and compaction. Past and on-going livestock grazing will continue to have a potential effect on soil hydrologic function because compacted cattle trails on the meadow could confine meadow runoff, causing small flood flow channels that could become erosive. However, these cattle trails would be dispersed across the meadow and would lilely not connect to form channels that carry large volumes of runoff, particularly since the Proppsed Action would result in flood flows being shallow and well dispersed across the meadow. Cattle trailing along the proposed fence is a particular concern, since these trails could run for significant connected distances along the fence. However, the meadow vegetation reinvigorated by the raised water table would provide stability for any potential erosion caused by flood runoff within the cattle trails. Cattle trails would be monitored by the grazing permitee and minor fence location adjustements made if necessary.

Surface organic matter, Proposed Action Direct Effects

Potential soil organic matter impacts associated with the Proposed Action would generally be limited to surface soils and direct effects would be similar to those described above for soil cover. Topsoil excavated from the borrow sites would be stockpiled and then spread over the surface of the partial channel fill and the meadow and hillside borrow areas, facilitating quicker establishment of vegetation on the newly constructed surfaces and returning the soil organic matter to existing levels. Construction traffic across the meadow would cause bare vehicle tracks but would not remove topsoil. Soil organic matter is a concern for the Proposed Action at the areas of the complete channel fill reach that are not covered by transplanted sedge mats. These exposed soils would consist of material excavated from the deeper layers of the hillside borrow areas, which contain substantially less organic matter than the topsoil layers. Seeding on these complete channel fill surfaces, as well as the raised water table, would facilitate vegetative regrowth that would provide soil organic matter in the future.

Surface organic matter, Proposed Action Inirect Effects

Indirect effects of the Proposed Action on soil organic matter would be beneficial, due to reinvigoration of meadow and riparian vegetation caused by the raised water table. Significant vegetative regrowth within 1-3 years is expected on bare soil areas created by the Proposed Action, resulting in substantail future incrases in soil organic matter. Vegetation establishment on the bare surface areas of hillside borrow soils not covered by transplanted sedge mats on the complete channel fill reach is expected to be quick since the surface of these areas would be within 1 foot of the restored water table. Within 1-3 years of implementation of the Proposed Action, soil organic matter throughout the project area is expected to be well in excess of 50% and would adequately support natural plant growth function.

Surface organic matter, Proposed Action Cumulative Effects

Cumulative effects to soil organic matter are similar to those described above for soil cover. Past vegetation management in the analysis area have not significantly altered soil organic matter and future vegeation treatments would maintain suface soil organic matters levels well in excess of 50% (USDA 2011). Vegetative cover and soil organic matter is robust throughout the areas that have been utlized for past cattle grazing. SNFPA ROD standards and guidelines for grazing limit the amount of grazing activity in the future so vegetative cover and soil organic matter development would continue to be well above soil quality standards for support of plant growth. The proposed fence around channel restoration treatments would aid the quick establishment of meadow and riparian vegetation that would contribute to soil organic matter.

Soil moisture regime, Proposed Action Direct Effects

Direct effects to soil moisture regime as a result of the Proposed Action would be similar to the groundwater retention effects described below. The Proposed Action would fill the incised mainstem stream channel through the meadow, raising the water table to within rooting depth of plants throughout much of the meadow. Under the existing condition, the incised channel causes the water table to drain significantly following the winter and spring runoff period, resulting in xeric vegetation such as sagebrush throughout the meadow. Shallow soil profiles in the meadow indicate that soils were wet for longer duration in the past, presumably prior to channel incision. The water table along the filled channel and adjacent meadow areas would rise and groundwater accumulates in the meadow during the first precipitation season after constructon of the Proposed Action. Soil moisture in the hillside borrow areas would be unaffected by the meadow restoration treatments.

Soil moisture regime, Proposed Action Indirect Effects

Soil moisture regime effects of the Proposed Action would primarily be direct effects, occurring within the first precipitation season after treatment.

Soil moisture regime, Proposed Action Cumulative Effects

Past, present, and reasonably foreseeable vegetation and grazing management activities in the project area would have little or no effect on soil moisture regime. Timber harvest and thinning of forest stands can slightly decrease soil moisture by exposing more soil surfaces to solar radiation. However, these changes are small and are likely to affect soil plant growth function. Grazing can potentially influence soil moisture regime if areas are excessively grazed, which could cause eroding flow channels in the meadow. However, SNFPA ROD standards and guidelines for grazing limit the amount of forage utilization allowed so such impacts are not expected. Cumulative effects to soil moisture regime would primarily be associated with the proposed meadow restoration treatment.

Cumulative Watershed Effects Model for Proposed Action

Under the Proposed Action, ERA values for the project area sub-watershed (1,738 acres) would remain well below the 12 percent threshold of concern after implementation of the proposed actions along with past, present, and reasonable foreseeable actions (see Figure 1 and Table 5). The results indicate that these actions would not cause alteration of surface runoff patterns within the watershed such that beneficial uses of water would be impacted.

Table 5. ERA values for Project sub-watershed (Proposed Action)

	Pre-Project ERA (percent of sub-watershed area)				Future Project ERA (percent of sub-watershed area)			
Sub-Watershed	Roads (System & Non-System	Veg Projects	Grazing	Total Pre-Project ERA	Proposed Action	Future Veg Project (Mapes)	Total ERA	Threshold of Concern
Thompson Creek	0.64%	1.3%	3.1%	5.0%	0.77%	0.3%	6.1%	12%

Sedimentation, Proposed Action Direct Effects

The Proposed Action could result in some short-term increase in sediment from land disturbances associated with temporary access routes, staging areas, and construction activities associated with riffle and channel fill treatments. However, project activities under Alternative A would be controlled by BMPs and design features that would prevent or minmize sediment production and delivery due to project work. BMPs at staging areas, hillside borrow areas, and along the access road would disperse drainage from those areas and prevent sediment delivery to any adjacent waters. Sediment generated from disturbed areas associated with channel and meadow treatments is not expected to leave the project area due to the relatively low meadow gradient and because the meadow borrow sites (ponds) and in-channel pooled areas behind raised riffle structures and the grade control structure would catch construction-generated sediment. Channel fill, partial channel fill, and riffle construction would occur during the low flow season. Partial channel fill would occur outside of live streamflow, as flows are directed into the remnant channel with the construction of the first plug. Raised riffle and grade control structures would be constructed in-stream during the low flow season and any associated fine sediment would be captured in the pools behind these structures or at downstream temporary catchment structures.

Sedimentation, Proposed Action Indirect Effects

The Proposed Action would result in returning channel flows to the meadow surface, allowing flood flows to access the valley floodplain, where sediments from upvalley overland flows could be deposited on the floodplain rather than being transported to downstream reaches of channel. Vegetation would be re-invigorated by the higher water table and would maintain long-term stability. Flood flow access to a vegetated floodplain would result in reducing streambank erosion and sedimentation by eliminating the concentrated flow velocities and stream energy within the gully. Sedimentation from the development of remnant channels is not expected to be higher than would normally occur in a meadow channel.

It may be postulated that the project would “starve” the system of sediment, both in the long term and downstream of the project area. Several key factors about the project area preclude this effect: 1) the small size of the watershed, low precipitation, and naturally broad meadow floodplain all contribute to a system with very little natural fine sediment production; and 2) natural channel meandering over time contributes a small amount of sediment to the system. The Proposed Action would allow sediment to deposit in the project area, rather than contributing sediment to downstream areas.

In the long term, and based on the response of similar projects, it is expected that within the first growing season after construction, plants will begin to colonize bare soil areas. Transplanted on-site vegetation is expected to have a 75%-80% survival rate. The vigorous vegetation on the meadow-elevation floodplain is expected to result in a reduction of sediment generation through the project area during the first year.

According to the FHWA design circular (US DOT 2005), native grasses are capable of resisting tractive forces up to approximately 1.2 pounds per square foot. Thus, the risk of losing plug surface soils would be highest in the first year after construction, before vegetation has a chance to take hold. Erman et al (1988) showed that snow depths can restrict floodplain area and confine flood flows. If this were to occur in the project area, greater flow depths during a flood would be realized, with accompanying increases in shear stress. Unvegetated areas, including fill surfaces in the near-term after implementation, would be most vulnerable to erosion as a result of such increased shear stresses. However, fill design criteria and vegetation transplants discussed above would prevent significant instability of the restored reach due to flood flows confined by snow.

All stream or meadow restoration techniques carry risk of erosion during floods, including techniques that utilize large rock riprap to harden stream banks and beds (Thompson 2002). A large input of sediment could potentially result from a partial fill segment failure. The risk of such an event would be highest in the first year after construction, before vegetation has a chance to take hold. However, this risk has been minimized in the design through the following design criteria: 1) the target design head differential from one partial fill to the next is low, one foot or less. This low differential is well within the rooting depth of plants so that downstream partial fill edges are protected via plant roots; 2) during construction, rooted vegetation (predominantly sedges) is planted along the downstream partial fill edges so that even if a large run-off event occurs in the first year after construction, the vegetation will provide physical protection from erosion; 3) topsoil excavated from the borrow sites would be stockpiled and spread over the surface of the completed fill to facilitate quicker establishment of vegetation on the newly constructed fill surface. Filled surfaces would beseeded with locally collected native grass seed; and 4) partial fill elevations are kept low to promote vegetation growth but are slightly higher than the adjacent floodplain so that overland flow is not likely to spill over the fill edge. The project will end at a constructed large rock valley grade control structure that provides a stable terminus for the project. Flood flows over this structure would be stair-stepped down this structure to the elevation of the existing channel bottom at the downstream end of the project, thus reducing the chance for headcutting to move up the valley from the action of falling water.

By and large, the partial channel fill meadow restoration projects that have been implemented in Plumas County since 2001 have withstood several years of significant flooding, with the vast majority of projects still meeting the restoration objective of restoring water tables and spreading high flows across the meadow floodplain. The most comprehensive field review of the condition of constructed partial channel fill projects was performed by PNF staff in 2011 for projects constructed between 2001 and 2007 in the Last Chance Creek watershed (see Table 6). All constructed plugs in these restored reaches were surveyed, although some of the plugs could not be located because the plugs had re-vegetated well and looked similar to the surrounding meadow landscape. Eighty-two constructed plugs were reviewed, with just over half of those exhibiting no evidence of flow erosion. Thirty percent of the plugs exhibited erosion of concern (an erosion rill at least 9 inches deep or a rill that runs the full length of the plug), but small beaver dams had effectively stabilized many of those rills. Additionally, 6 plugs have been stabilized with rock or other techniques since the 2011 survey. Field checks conducted in 2018 for the Last Chance Creek watershed projects found no additional significant plug erosion issues following the heavy floods of 2017.

While project observers commonly assert that a plug that has experienced surface erosion has “failed,” a closer look at meadow flow dynamics demonstrates that a partial channel fill project can withstand some segments of plug erosion. Project objectives to restore the meadow water table and floodplain connectivity are compromised only when a rill across a plug develops that is lower than the meadow surface stream channel. Only 3 of the 82 plugs (4%) along Last Chance Creek projects were completely breached by flood flows, meaning that the stream’s lowest seasonal flows run through the plug, causing a lowering of the water table and loss of floodplain connection in those short segments of the restored reach. At these locations, the breached plug does fail to provide vertical control of the elevation of the meadow stream channel, although the channel elevation is typically found to be held close to the meadow surface by the next constructed fill downstream. Figure 4 shows a plug that on the Jordan Flat project that was completely breached by flood flows and caused a lowering of the meadow stream elevation. However, a recently constructed beaver dam has raised the channel elevation and water table at this location and the project is still serving its intended purposed of raising the meadow water table and restoring floodplain function.

Table 6. 2011 Plug Condition Survey Results for projects constructed in Last Chance Creek watershed

Reach No.	Reach Name	# of plugs surveyed	# of plugs without evidence of flow erosion	# of plugs with minor rilling only	# of plugs with deeper rills	# of breached ("failed") plugs	# of plugs with beaver activity	# of plugs with deep rills fixed by beaver
LC1	Alakli Flat (North Alkali)	9	4	2	3	1	3	1
LC2	Painted Rock (Alkali Riparian)	6	6	0	0	0	2	0
LC3	Ferris Fields (Headquarters Riparian)	19	6	5	8	0	4	3
LC4	Jordan Flat (Jordan Flat Riparian)	9	2	3	4	1	3	0
LC5	Bird - Jordan (Bird Pasture)	10	2	2	6	0	8	4
FC1	Ferris Creek (Ferris Fields Riparian)	9	6	2	1	0	0	0
BF1	Big Flat (Cottonwood Creek)	7	5	0	2	1	0	0
CC1AB	Clarks Creek	13	11	1	1	0	6	0
	Total	82	42	15	25	3	26	8
			51%	18%	30%	4%	32%	

Notes: - "Deeper rills" are rills that are more than 9 inches deep or that run the full length of the plug
- # of plugs with major rills includes plugs that are breached

The 3-mile-long project on Red Clover Creek that was constructed on USFS lands near the Poco Creek tributary in 2010-2011 has experienced the most plug erosion of any partial channel fill restoration constructed on USFS lands in the upper Feather River watershed. However, the project is still mostly meeting the objective of raising the meadow water table and restoring floodplain connection, primarily due to beaver activity that has stabilized many spots of plug erosion and also due to stout sedge vegetation that is maintaining the designed plug elevations along the downstream and upstream edges of the plugs. This is particularly evident along the 1.5 mile reach above Chase Bridge. The lower portion of the project downstream of the bridge has experienced breaching of 3 plugs in the recent flooding of 2017 and 2019, causing a few segments of stream that are several hundred feet long where the stream channel runs through the breached plugs and the meadow water table elevation has lowered below the rooting depth of meadow vegetation. High flood flow stresses and the narrow width of the natural valley floodplain along this reach have been identified as primary causes of the instability of the restoration treatments along this reach (Hoffman 2014). By contrast, the 4 miles of partial channel fill restoration on Red Clover and McReynolds Creek on private lands immediately upstream of the USFS Poco Creek project has remained remarkably stable throughout all floods since its construction in 2006. Similarly, the 2.6 mile long Dotta Canyon project along the upper reach of Red Clover Creek has experienced very little plug erosion since its construction in 2013. Erosion of channel fills similar to erosion that has compromised the integrity of the downstream portion of the Red Clover Poco restoration project is not expected for the Thompson Meadow Proposed Action because flood flow magnitudes will be much less for the smaller Thompson Creek watershed and because the Thompson Meadow floodplain is proportionately wider than the floodplain at the lower reach of Red Clover Poco.

For Thompson Meadow, if future floods cause erosion of some segments of the constructed project, volumes of fine sediment eroded would be limited by large rock design features such as the grade control structure at the downstream end and the rock sleeper weirs buried within the complete fill reach. Therefore, the design is such that minimal to no damage would occur to the channel immediately downstream of the project area. At a larger watershed scale, sediment volumes from such an erosion event would be small compared with sediment that typically flows during large floods and would not damage to private or public structures located further downstream on Red Clover Creek (such as Chase Bridge, Notson Bridge, or irrigation diversion structures near the mouth of Red Clover Creek).

If a partial fill segment is cut through that would compromise the integrity of the project, the segment would need to be repaired. Sometimes this work can be accomplished by hand with vegetation, or it may require heavy equipment. While this occurrence is rare, successful partial segment repair work has occurred in the past at similar projects in the upper Feather River watershed on private and USFS lands at Last Chance Creek (Jordan Flat), Long Valley Creek, Boulder Creek and Smith Creek. The Proposed Action is not likely to require repair work because of conservative design criteria with one-foot or less drop off of all partial fill segments and a sufficiently wide floodplain.

Sedimentation, Proposed Action Cumulative Effects

ERA calculations do not indicate that past, present, and future activities would alter watershed hydrology to the point that a cumulative adverse effect, such as sedimentation that would impact beneficial uses, would occur. Cumulative effects on sedimentation from past vegetation management in the analysis area are not likely to be affected by the Proposed Action because the Proposed Action takes place at the downstream end of the analysis area, and the cumulative effects of soil erosion would not move up the slope. It is possible, however, that the Proposed Action could reduce detrimental effects of any sediment generated upslope because of the restored floodplain function, which would filter sediments from overland flows before they enter the stream channel. Cumulative effects from past and current livestock grazing have contributed to current conditions and are considered in the cumulative watershed effects analysis. On-going livestock grazing will continue to have an effect on sedimentation, however that effect is expected to be diminished under the Proposed Action versus current conditions because the Proposed Action will result in a fence being built to protect the riparian and adjacent wet meadow area and because recent SNFPA ROD standards and guidelines for grazing are protective of channel and floodplain stability. The Proposed Action would also result in improved vegetative vigor that can better withstand grazing pressure when grazed. Cumulative effects from erosion on the access road will improve through the proposed road improvements (rolling dips) that disperse runoff and prevent rilling of the road surface and embankments.

Figure 4: Photos of a constructed plug breached by flood flows on Jordan Flat project, and then repaired by beaver dam. Above photo is April 2015. Below photo is August 31, 2018.

Groundwater retention, Proposed Action Direct Effects

The proposed action is expected to significantly improve groundwater retention**.** In the current incised condition, groundwater primarily contributes to surface water streamflow early in the season, soon after spring precipitation ends. This is because the depth of the incision acts like a drain on the precipitation stored as groundwater in the meadow. A study of Sierra Nevada meadows included the proposed

Thompson Meadow project area and estimated that zero groundwater discharge to the stream occurred from July 1 to September 30 in 2012 and 2013 (USDA 2015). The existing deep incision causes groundwater to "fall" out of floodplain more quickly, from a low hydraulic gradient within the meadow soils to the incised stream gradient that is located several feet below the meadow surface (a very steep hydraulic gradient from the meadow water table to the incised stream). This lowering of the water table is directly analogous to the resultant cone of depression that occurs due to groundwater well pumping (Essaid 2014).

Groundwater retention, Proposed Action Indirect Effects

The Proposed Action would allow groundwater to release more slowly. The drain effect associated with the current incised stream channel would be significantly reduced due to the low elevation difference and hydraulic gradient associated with the restored meadow water table and the restored stream channel elevations, which would be within 1-2 feet of the water table. The Proposed Action would restore the meadow water table close to natural elevations and return stream flow to the surface of the meadow so that the direction and gradient of groundwater flow would be converted from a steep direction toward the incision to a flatter direction down the length of the valley (Ohara 2013), potentially resulting in groundwater contribution to the stream later in the season. This would cause groundwater to remain within meadow soils much longer through the spring and summer seasons.

Groundwater retention, Proposed Action Cumulative Effects

Cumulative effects to groundwater retention under the Proposed Action would be positive and would be associated almost exclusively with the meadow restoration treatment actions. Past, present, and reasonably foreseeable effects to groundwater retention associated with timber and vegetation management activities are comparatively very small. Such effects stem from improved groundwater retention due to less interception of precipitation after timber and vegetation is thinned, offset by increased drying of soils when surfaces are exposed to more solar radiation after thinning. Similarly, grazing activities have little effect on groundwater retention, other than possible compaction and loss of infiltration (discussed above in the soils section).

Water temperature, Proposed Action Direct Effects

In the short term during construction, water temperatures within the project area may become warmer at isolated areas as the meadow borrow sites (ponds) and pools behind raised riffle structures begin to fill. Water temperatures downstream of the project area are expected to remain at background levels, due to the influence of tributary and groundwater flows. Surface water in the meadow borrow sites and ponds, however, would be subjected to increased solar radiation, which is likely to warm their surface water temperatures.

Water Temperature, Proposed Action Indirect Effects

Indirect effects are considered later in time and away from the project area. Effects to water temperature from the Proposed Action would primarily be indirect effects. After construction, monitoring of similar projects has indicated that temperatures remain cool in pond bottoms (see Figure 5). Warmer temperatures at the surface of the existing channel borrow sites are not expected to affect instream temperatures because these ponded areas are only connected to flowing areas during periods of flooding, when water temperatures throughout the restored meadow would be cool.

After construction, re-introduction of flowing water into remnant channels on the surface of the meadow is expected to re-invigorate the wet meadow species along the banks. It is expected that the vegetation recovery combined with the action of flowing water and background sediment supply, would begin a narrowing and deepening of the channel, leading to well-vegetated undercut banks with riffles and deep pools resulting in a lower width-to-depth ratio. This channel geometry, and the increased bank and vegetative shading, would contribute to cooler water temperatures. This process of developing undercut banks would be limited to the reaches of the Proposed Action where the base flow channel is redirected to the meadow surface; that is, undercut banks are not expected to develop along the stream reaches treated with raised riffles. Development of undercut banks may be a slow process (several years to decades) because of the low flow rates and small sediment supply associated with this small watershed. Existing water temperature in these reaches will be maintained by the small amount of perennial surface flow in the stream, with cooler temperatures expected in the deeper levels of the pools behind the raised riffle and grade control structures.

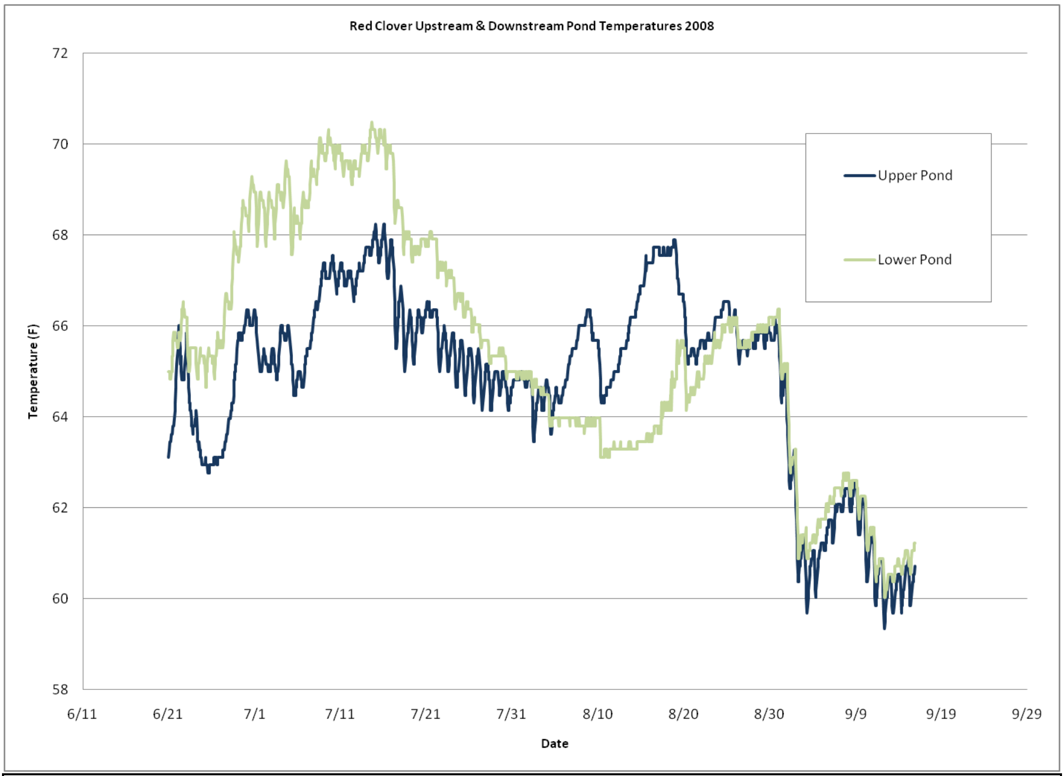

Figure 5. Water temperatures in pond bottoms of the top-most and and lowest ponds of the Red Clover McReynolds Project area. Data from the Red Clover McReynolds project show that temperatures remain cool in pond bottoms.

Instream temperature through the summer months is expected to improve within the project reach as a result of the Proposed Action due to increased groundwater retention. The Proposed Action is expected to improve groundwater retention. Groundwater retained in the meadow and released slowly to the stream through the summer would benefit stream temperature. During warm periods, groundwater input to streams lowers stream temperature and buffers diurnal stream temperature variations (Loheide 2006). Loheide observed increased groundwater input and decreased stream temperatures from a 1995 pond and plug project completed on the Beckwourth Ranger District (Big Flat at Cottonwood Creek, a tributary to Last Chance Creek) and stated that pond and plug restoration may derease maximum stream temperatures by more than three degrees centigrade. Monitoring from similar past projects indicate that there is an overall decrease in temperatures (see Figure 6). At a larger watershed scale, changes to stream temperature as a result of the Proposed Action are expected to be small and immeasurable.

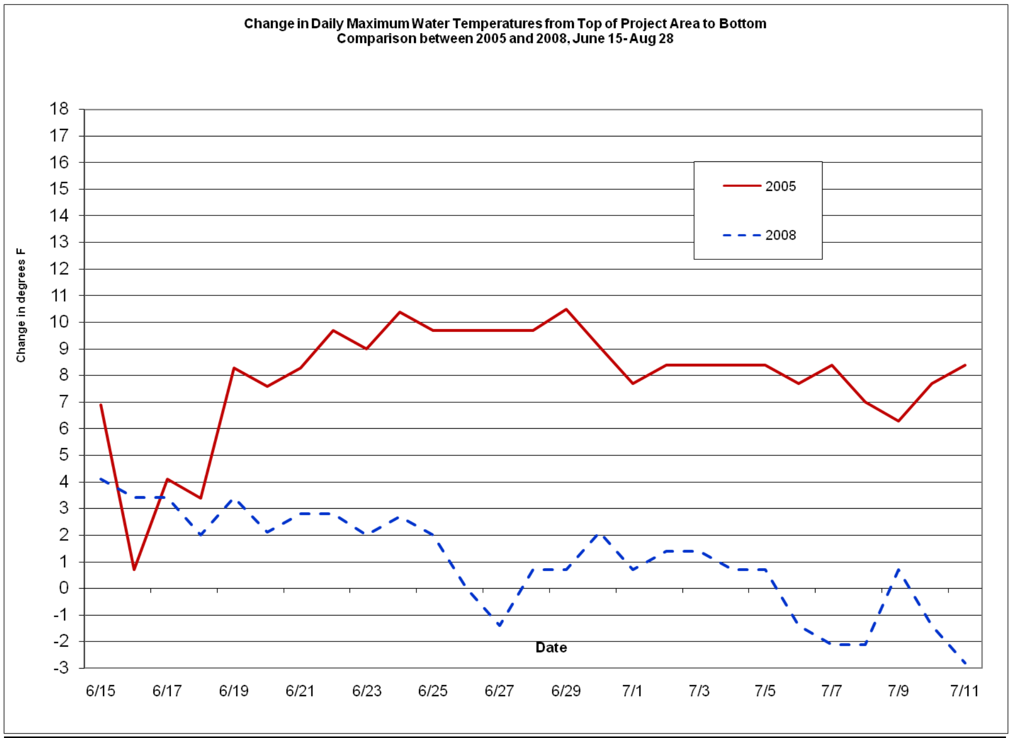

Figure 6. Increase in water temperature from top to bottom of Red Clover McReynolds Project area in pre-project (2005) versus post project (2008) conditions. Negative numbers indicate that water temperatures cooled from the top to the bottom of the project area. (Data after July 11 are unreliable due to the possibility that the continuous recording thermometers were out of the water).

Water Temperature, Proposed Action Cumulative Effects

ERA calculations indicate that the wide, shallow stream channel conditions that have impacted stream temperatures within the project area are not likely to be exacerbated as a result of changes in watershed hydrology caused by land management activities. Cumulative impacts to water temperature from past timber management activities are expected to be minimal because water is not perennial on the timbered areas of the watershed above the project area. Timber management has not increased solar radiation to water in the project area, because past and future timber cutting is not close enough to perennial surface water in the project area to affect water temperature under either alternative. On-going grazing management has the potential to cumulatively impact water temperature if shade species such as willow are grazed or if stream channel structure is impacted. However this likelihood is negligible because standards and guidelines in the 2004 SNFPA ROD prevent excessive grazing pressure on channels and floodplains. Also, the newly restored channel area and wet meadow will be fenced off and grazing restricted for several years post-project. The fenced area will be managed post-project so as to minimize impacts to vegetation. Shade provided by willows can help decrease the warming effects of direct sunlight on the water. Current standards and guidelines for grazing do not allow more than 20% use of willow. This standard should allow for some annual willow growth, leading to a trend toward more shade and cooler water temperatures. Also, willows are not preferred by cattle unless other forage is unavailable. The Proposed Action is expected to support the growth of shade-producing willows along the stream channel under current standards and guidelines, which reduce the impacts of grazing on any plants along the streambank. This should cumulatively lead to lower water temperatures within and near the project reach.

Stream flow, Proposed Action Direct Effects

Restoration construction activities would occur during the low flow season. There would be short-term direct effects to flow during construction in the partial channel fill reaches. For these reaches, surface flow would be retained within the channel borrow areas (ponds) throughout the time when construction occurs. The effect to downstream flows in larger streams (like at the confluence with Red Clover Creek) would be negligible because the Thompson Creek flow rate during the anticipated time of construction is very small. DWR monitoring at the downstream end of the project area found an average maximum daily flow of 0.18 cfs from August 15 through November 1 of 2016 (an above normal precipitation year). Surface flow would resume at the downstream end of the project area after construction is complete and after sufficient fall precipitation has occurred to recharge the ground water table and fill the channel borrow areas. Proposed channel fills would be constructed to have a groundwater permeability that is similar to adjacent meadow soils. Throughout the period of construction and water table recharge, water retained in the project area would continue to flow down valley as groundwater, likely emerging as surface water at some point downstream.

Red Clover Creek is a tributary stream to Indian Creek. In 1950, the State of California completed a determination of the rights of various claimants to the water of the Indian Creek system (Decree No. 4185, commonly known as the "Indian Creek Decree")(Superior Court of CA 1950). No decreed diversions exist along Thompson Creek or McReynolds Creek, which flows to Red Clover Creek. Approximately one dozen decreed diversions exist on Red Clover Creek and its tributaries upstream of the confluence with McReynolds Creek, but most are no longer being utilized. The remaining 6 decreed diversions on Red Clover Creek, totaling a maximum of 2.15 cubic feet per second, are located more than 10 miles downstream of the proposed project, within one mile of the creek's confluence with Indian Creek in Genesee Valley. At least one of these diversions is used every year and is an important source of irrigation water. Most of the water in Red Clover Creek that is available to these users comes from several small streams on the north side of Mount Ingalls that flow to Red Clover Creek in the canyon immediately above Genesee Valley, several miles downstream of the proposed project (DWR 1946). Construction of the Proposed Action during the low flow season is not expected to result in a measurable change in the amount of water available to decreed claimants in Red Clover or Indian Valley.

Another direct effect on flow would be the creation of 9 ponds (less than 1.0 acre total area) under this alternative within the project area. The water level in the ponds would not be connected to surface streamflow during most of the year, particularly in summer months, and would rise and fall with the groundwater level. Hydrologically, the ponds act as floodplain (i.e. groundwater retention and release) and low velocity regions during overland flow events. Ponds on similar projects were studied and found to act as groundwater recharge zones, sustaining meadow groundwater levels during the summer (McMahon 2013). Pond evaporation rates were found to be similar to evapotranspiration rates in restored meadows (USDA 2015). Although evaporation accounted for 40 to 70% of summer water loss in the ponds, the remainder of the water lost from ponds was recharged to the local meadow aquifer.

Streamflow, Proposed Action Indirect Effects

As mentioned above for water temperature, effects on streamflow are mostly indirect, and are multi-fold and synergistic. Changes to streamflow are primarily due to the restored retention and release function of the shallow meadow floodplain. The Proposed Action would reduce the area of the channel, so that flows overbank onto the floodplain more frequently. The more frequent overbanking is likely to lessen the sharp peaks and declines in stream flows due to precipitation events. It would also release that water later in the season, thus potentially increasing base flow downstream of the project.

Benefits to late season streamflow due to enhanced groundwater retention can be offset by increased evapotranspiration due to re-invigorated riparian vegetation in the meadow. A mapping algorithm applied to two reaches that were treated with pond-and-plug on Last Chance Creek on Plumas National Forest showed that daily evaprotranspiration rates were roughly double the rates observed on degraded reaches that had not been restored (Loheide 2005).

Five previous studies in the Sierra Nevada have demonstrated changes in streamflow following meadow restoration. These studies indicate a range of responses but generally demonstrated that restoration increases summer baseflows downstream of restored meadows. Channel filling of an incised gully in Indian Valley (south of Lake Tahoe) resulted in increased total summer outflow that was 5-12 times greater than total summer outflow before restroration (Hunt 2018). Pond-and-plug restoration of Trout Creek near Lake Tahoe resulted in higher water table elevations, reduced streamflow during the early part of the snowmelt season, and increased mid-summer streamflow within the project area; post-restoration streamflow in late summer was about the same as pre-restoration flow (Tague 2008). Water temperature data were used to infer increased baseflow in restored meadow reaches relative to unrestored reaches on Cottonwood Creek (Big Flat) on Plumas National Forest (Loheide 2006). Hydrologic modeling applied to a pond-and-plug restoration project in Lassen County indicated a decreased duration of base flow at the midpoint of the restored meadow reach (Hammersmark 2008). The decreased mid-meadow baseflow was attributed to increased evapotranspiration and to loss of groundwater that would have drained to the incised channel pre-project but stayed as groundwater in the post-project condition and flowed out of the meadow downstream as either shallow groundwater or overland flow. Baseflow downstream of the restored reach was reported to have increased after restoration, but was not quantified.

A modeling study for the large, 96 square mile Last Chance Creek watershed above Doyle Crossing in Plumas County that included 9 miles of meadow pond-and-plug restoration compared the surface flow response for the restored and unrestored using idential climate conditions observed from 1982-1993 (Ohara 2013). The model predicted a 10-20% decrease in flood peaks for the wettest year and baseflow increase of 10%-20% for the following baseflow season. This effect of reduced flood peaks is illustrated in unpublished data collected at Big Flat, a small meadow within the same study watershed. The higher flood peaks recorded at the upstream end of the meadow in winter and spring 2006 were slightly reduced at the downstream end of the restored meadow (Figure 7). In meadows that are located in watersheds that are too small or too dry to have large volumes of regional groundwater flow, erosion and restoration are unlikely to greatly affect groundwater or streamflow either positively or negatively (USDA 2015). This expectation is also demonstrated by the Big Flat data, which shows improvements to streamflow early in the runoff season (May 2006) but little or no change by summer (Figure 8). The early season flow benefit was found to be statistically significant in a 2011 data analysis (Cawley 2011). Similarly, unpublished data for the stream gage at Doyle Crossing that compares streamflow for two similar years of precipitation (2002 and 2008) shows little difference in stream flow magnitude before and after restoration for the months of July, August and September (Figure 9). A small increase in baseflow is indicated, which may correlate with the increased baseflow that the Ohara model predicted for an unusually wet season.

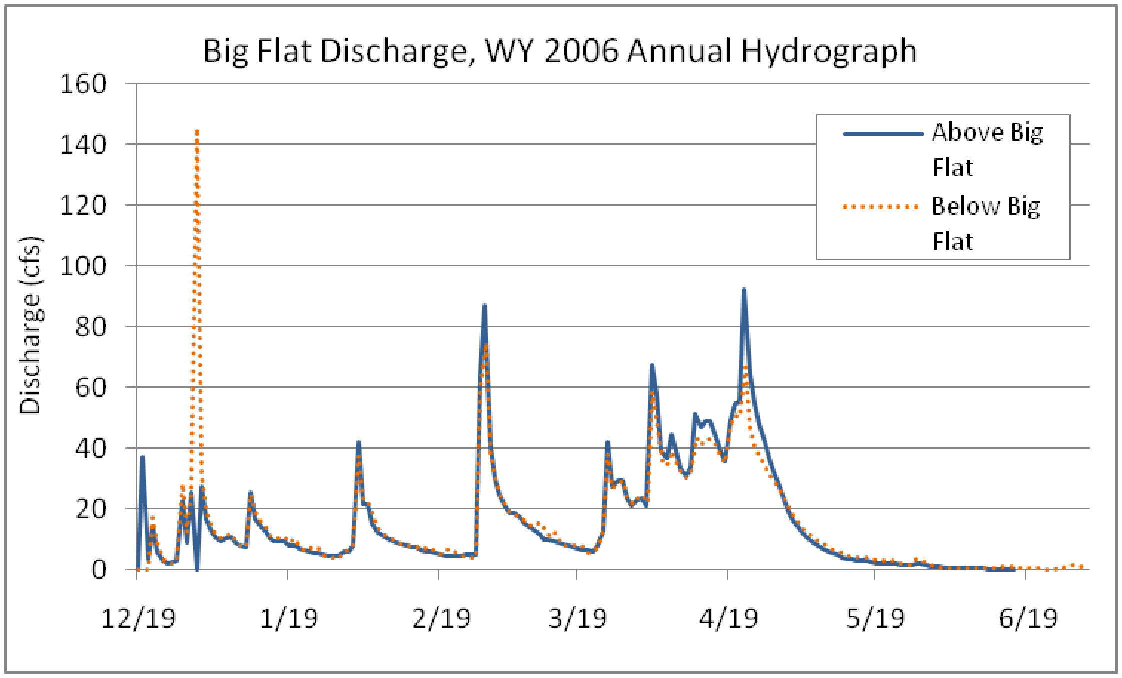

Figure 7. A series of storm event hydrographs from the continuous recording stations above and below the Big Flat pond and plug project area.

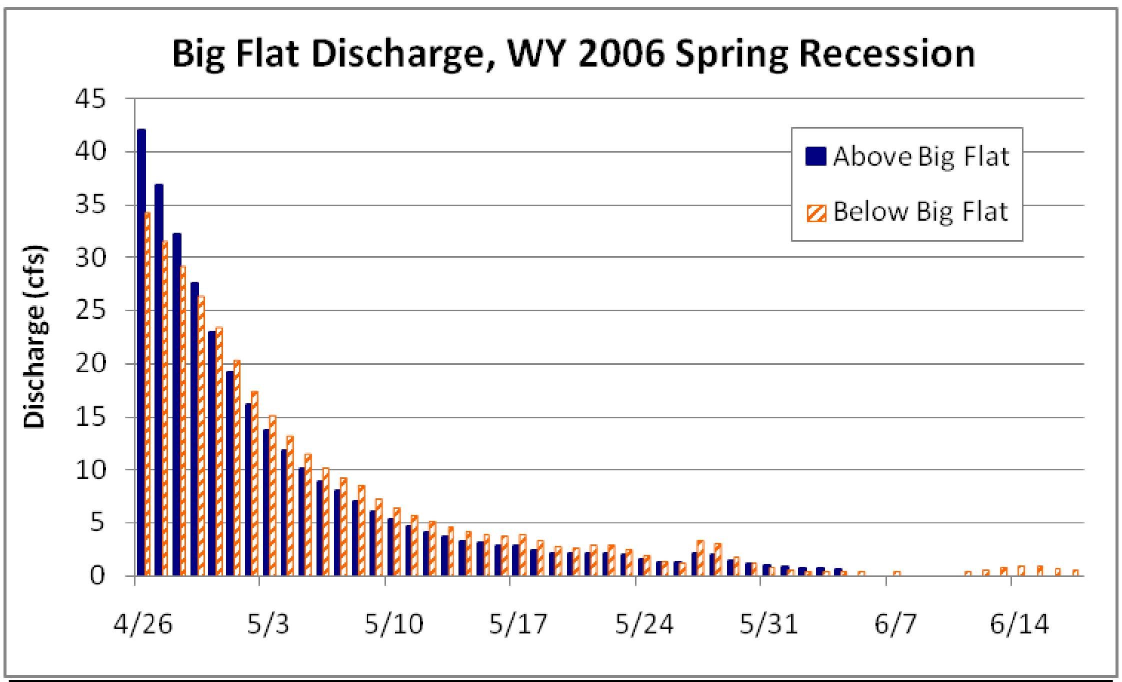

Figure 8. Spring stream flow recession in 2006 at Big Flat.

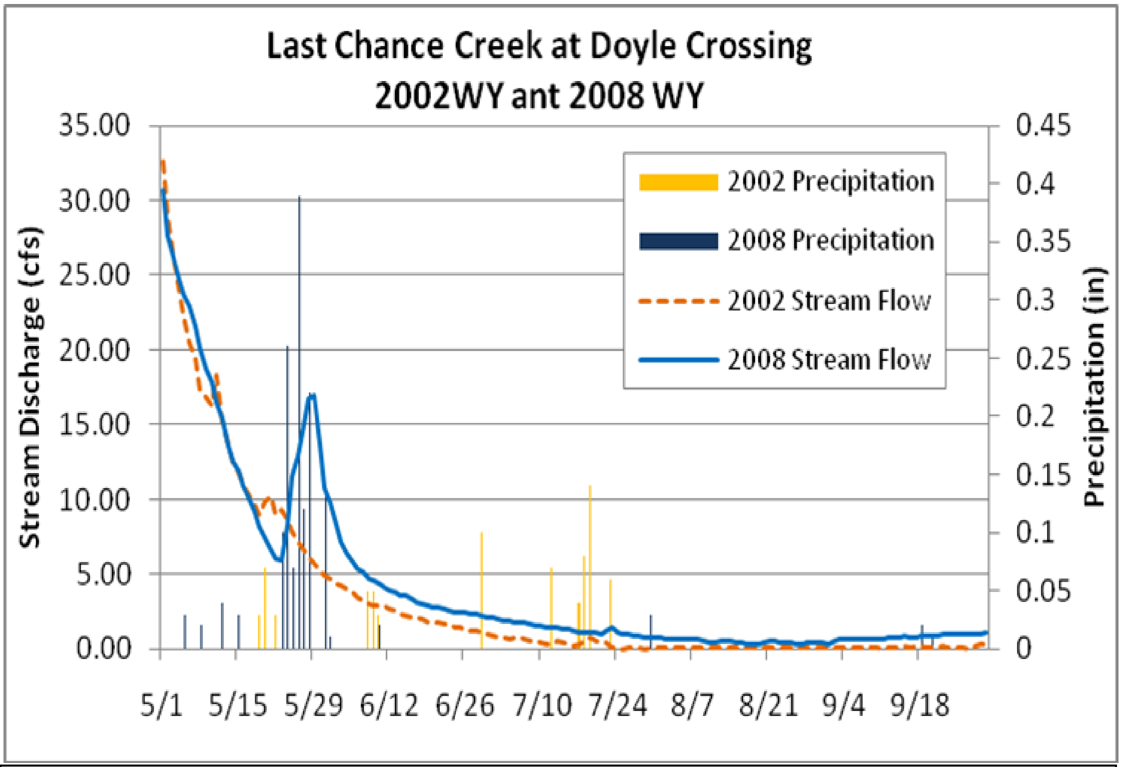

Figure 9. Flow and precipitation data from two comparable water years. 2002 represents pre-project conditions, and 2008 represents post-project conditions of the 7.75-mile Calfed Upper Last Chance Creek Restoration Project (construction completed during the years 2003-2007).

These studies all illustrate the interdependence between watershed and meadow hydrology, bedrock and meadow aquifers, and surface and groundwater flow through the meadow. At a watershed scale, climate and geology are likely to be more important controls on meadow groundwater processes than erosion and restoration (USDA 2015). All of the studies that reported increases in baseflow after restoration also reported that overbank flooding during winter and spring, which would occur for the Proposed Action, was an important process in recharging meadow aquifers.

Existing studies generally indicate minor improvements in summer streamflow following restoration. None of the predicted changes are large enough to affect downstream water uses and none are predicted to negatively impact downstream water uses. Therefore, indirect effects to streamflow as a result of the Proposed Action are not expected to be large enough to significantly impact downstream users or beneficial uses of water. This expectation is reinforced by a monitoring study that was performed for Plumas National Forest. A statistical analysis of 11 years of continuous streamflow data taken at Notson Bridge on Red Clover Creek indicated no apparent statistical trend in streamflow during the low flow late season (no increase or decrease in flow) (Cawley 2011). This bridge is located 6 miles downstream of large-scale pond-and-plug treatments that occurred on Red Clover Creek between 2006 and 2011 and 5 miles upstream of the nearest irrigation diversion from Red Clover Creek. Given the small area of meadow that is proposed for restoration relative to the amount or restoration that previously affected Red Clover Creek, the Proposed Action clearly will not significantly affect streamflow either positively or negatively at the location of the nearest downstream water use diversion.

Streamflow, Proposed Action Cumulative Effects

Stream flow emanating from the bottom of any watershed is cumulatively affected by watershed conditions. The existing degraded condition of the project area has significantly altered the natural streamflow regime of the meadow. The proposed project would restore floodplain function and move the meadow back toward natural hydrologic function. ERA calculations presented above indicate that the management activities of the recent past and the activities proposed for the present and near future do represent a significant risk that surface runoff patterns or timing would be altered again toward degraded conditions. If past timber management activities removed enough vegetation, then it is possible to contribute to a cumulative increase in streamflow. However, not enough vegetation has been removed to measurably detect a change to streamflow from timber management (Troendle et al 2007).

On-going cattle grazing has contributed to the existing condition in the project area, which is characterized by an deeply incised channel in a drying meadow. Channel incision affects streamflow by reducing season-long surface and ground water interaction. In the current condition, groundwater primarily contributes to surface water streamflow early in the season, soon after spring precipitation ends. This is because the depth of the incision acts like a drain on the precipitation stored as groundwater in the meadow. The Proposed Action would return stream flow to the surface of the meadow, so that seasonal groundwater in the floodplain can contribute more slowly (i.e. later in the season) to surface water streamflow. It is basically a matter of gravity. The existing deep incision allows the groundwater to “fall” out of floodplain more quickly. The Proposed Action would allow groundwater to release more slowly. Current grazing standards and guidelines do not allow for more than 20% alteration of stream banks from cattle grazing. This standard is expected to lead to long term bank stability, so that future channel incision, and its resultant effect on streamflow, would not be caused by cattle grazing. The Proposed Action would support this current standard because grazing would be restricted in the riparian area for several years following restoration and would be closely monitored in sub-sequent years.

Floodplain Function, Proposed Action Direct Effects

Three key aspects of floodplain function are sediment, water temperature and stream flow. These functional processes are discussed separately above. The Proposed Action would directly affect the frequency with which the channel floods the meadow floodplain. The existing stream channel is deeply incised such that only the largest flood flows would access the meadow floodplain. Even the large peak flood of 2017, estimated throughout the upper Feather River watershed to be a flood flow that has only been exceeded once or twice in the past 80 years, did not flow higher than the incision depth and reach the meadow surface within the project area (Figure 10). Flood modeling for the Proposed Action design has been performed using the US Army Corps of Engineers Hydrologic Engineering Center’s River Analysis System (HEC-RAS) (USACE 2016). This modeling demonstrates that flood flows are annually expected to reach access the meadow floodplain throughout the project reach.

Figure 10: Photos of the headcut on the mainstem of Thompson Creek near the downstream end of the project area. Above photo is during low flow season (June 2015). Below photo is during peak flood event of February 9, 2017. Note that, due to the incised stream channel, stream flow does not access the meadow floodplain even during this

Floodplain Function, Proposed Action Indirect Effects

Returning the channel to the elevation of the meadow would restore 47 acres of floodplain and meadow and 0.68 miles of riparian and aquatic habitat. The higher water table would be available to the rooting zone of the remnant wetland plant community in the meadow, and reduce invading xeric species. Groundwater recharge of the meadow would begin immediately and occur throughout the floodplain, over the first one to three winters. Where past restoration efforts have similarly raised the water table, wetland vegetation has resumed dominance (Hunt 2018). Changes in riparian and meadow plant communities are expected to take one to three years for a noticeable response, and possibly three to eight years for vegetation on disturbed soil to develop and mature. Plant community characteristics would be monitored as an indirect measurement of floodplain function, based on the presence of moist community plants on functional floodplains versus xeric community plants that are found on uplands. The Proposed Action is expected to convert the near-gully plant community from primarily a xeric community (i.e. dominated by sagebrush), to a moist community (i.e. dominated by sedge). This conversion would be measured by the dominance of the plant community along a moisture gradient (currently >50% sage converted to >50% sedge). Streamflow, water temperature, and sediment are all interconnected with floodplain function. See discussions above for expected effects of the Proposed Action on these specific attributes of floodplain function.

Floodplain Function, Proposed Action Cumulative Effects

The purpose of the proposed action is to restore channel and floodplain function within the project area. Past projects have demonstrated that pond-and-plug treatments effectively restore floodplain function. ERA calculations indicate that past, present, and future mangement activities, if properly implemented, would not alter surface runoff patterns or timing to the point that cutting of the channel above natural rates would occur and again impact floodplain function. Past timber management on the slopes is not likely to have affected floodplain function because of the distance between the activities and the meadow floodplain. This would continue to be the case under either alternative. On-going grazing can affect the vigor of floodplain vegetation, however, current grazing standards and guidelines are designed to ensure maintenance of floodplain vegetation. The Proposed Action would support the maintenance of floodplain vegetation while still allowing grazing under current standards and guidelines, because floodplain moisture would be enhanced under this alternative.

Alternative B – No-Action

Direct and Indirect Effects

Soil stability/Effective soil cover, No Action Direct Effects

Under the No Action Alternative, effective soil cover would be unchanged. Soil cover in the proposed hillside borrow areas and meadow area would continue to meet current soil quality standards and support soil plant growth and hydrologic functions. Unvegetated and eroding streambanks along the mainstem channel would not be stabilized and would continue to be subjected to high stream flow stresses associated with flood flows confined to the incised channel. Headcuts that exist where the westside tributary channels meet the mainstem, as well as the large headcut on the mainstem channel near the downstream end of the project area, would not be stabilized.

Soil stability/Effective soil cover, No Action Indirect Effects

Headcuts on the mainstem channel and westside tributary channels would likely erode further upstream in future flood events, causing further erosion and loss of meadow soils to the downstream channel.

Soil stability/Effective soil cover, No Action Cumulative Effects

Reasonably foreseeable future actions would not cause significant impacts to effective soil cover in the project area. Cumulative effects from past vegetation management in the analysis area have not significantly altered soil cover and future vegeation treatments would maintain the areal extent of soil cover in excess of 70% (USDA 2011). On-going livestock grazing would continue to have a potential effect on soil cover, particularly where cattle trails form. However, such trailing would be dispersed across the meadow and would not significantly impact plant growth function. SNFPA ROD standards and guidelines for grazing limit the amount of meadow forage that can be utilzed by grazing.

Soil porosity and compaction, No Action Direct Effects

Under the No Action Alternative, soil porosity and compaction would be unchanged. Existing soil compaction in the proposed hillside borrow areas and meadow area is minimal and soils would continue to properly support soil plant growth and hydrologic functions.

Soil porosity and compaction, No Action Indirect Effects

There are no anticipated indirect effects to soil porosity and compaction that would result from the No Action Alternative.

Soil porosity and compaction, No Action Cumulative Effects

Reasonably foreseeable future actions would not cause significant impacts to soil porosity and compaction in the project area. Cumulative effects from past vegetation management and grazing activities in the analysis area have not cause significant compaction. Future vegeation treatments would not result in significant area of soil compaction. Livestock grazing would continue to have a potential effect on soil hydrologic function because compacted cattle trails on the meadow could confine meadow runoff, causing small flood flow channels that could become erosive. However, these cattle trails would be dispersed across the meadow and would lilely not connect to form channels that carry large volumes of runoff. Grazing in the area of the westside tributary channel headcuts would be a concern since cattle traffic could exacerbate these headcuts, particularly if the soils are wet during grazing.

Surface organic matter, No Action Direct and Indirect Effects

There are no anticipated indirect effects to soil porosity and compaction that would result from the No Action Alternative. Soil organic matter would remain abundant, well over soil quality standards, and would continue to support soil plant growth function.

Surface organic matter, No Action Cumulative Effects

Reasonably foreseeable future actions would not cause significant impacts to soil organic matter in the project area. Cumulative effects from past vegetation management in the analysis area have not significantly altered soil organic matter and future vegeation treatments would not significantly displace topsoil so soil organic matter would be maintained at current levels (USDA 2011). On-going livestock grazing would have little or no impact on soil organic matter since the meadow is well vegetated and forage utilization is limited by SNFPA ROD standards and guidelines.

Soil moisture regime, No Action Direct and Indirect Effects

Under the No Action Alternative, soil moisture regime in the project area would be unchanged. The incised channel along the mainstem would continue to cause the water table to drain significantly following the winter and spring runoff period, preventing the establishment of seasonally wet meadow vegetation that has historically existed along the channel.

Soil moisture regime, No Action Cumulative Effects

Reasonably foreseeable future actions would not cause significant impacts to soil moisture regime in the project area. Cumulative effects from recent vegetation management and grazing in the analysis area have not significantly altered soil moisture regimes since it appears that the channel incision occurred decades ago. Grazing in the area of the westside tributary channel headcuts would be a concern since cattle traffic could exacerbate these headcuts, potentially causing further drying of meadow soils.

Sedimentation, No Action Direct & Indirect Effects:

The No Action alternative does not generate direct effects. Under existing conditions, sedimentation is generated within the project area by the erosion of gully walls along the channel. Under the No Action alternative, this trend is expected to continue. The difference between the Proposed Action versus the existing condition is that sediment will be deposited and contribute to bank and floodplain maintenance on the surface of the meadow under the Proposed Action, whereas in the existing condition, sediment is transported through the project area, causing negative impacts on water quality and fish habitat within, and downstream of, the project area. Under the No Action Alternative, rilling and surface erosion along the existing access road would not be treated. However, since erosion does not appear to connect to surface water, sedimentation impacts are not expected from the road.

Sedimentation, No Action Cumulative Effects:

Cumulative effects due to past and future vegetation management would be the same for both alternatives, and are discussed above. Future vegetation treatments are not expected to deliver sediment to streams in the project area. On-going livestock grazing would continue to have an effect on sedimentation, and is likely to be greater under the No Action alternative, because the vegetation under the existing condition is already stressed from a lack of moisture.

Groundwater retention, No Action Direct and Indirect Effects

Under the No Action Alternative, groundwater retention in the project area would be unchanged. The incised channel along the mainstem would continue to cause the water table to drain significantly following the winter and spring runoff period, preventing the establishment of seasonally wet meadow vegetation that has historically existed along the channel.

Groundwater retention, No Action Cumulative Effects

Reasonably foreseeable future actions would not cause significant impacts to groundwater retention in the project area. Cumulative effects from recent vegetation management and grazing in the analysis area have not significantly altered groundwater retention in the project area since it appears that the channel incision occurred decades ago. Grazing in the area of the westside tributary channel headcuts would be a concern since cattle traffic could exacerbate these headcuts, potentially causing further drying of meadow soils.

Water Temperature, No Action Direct and Indirect Effects

The No Action alternative does not generate direct effects. Under the No Action alternative, no change is expected to the existing trend of water temperatures.

Water Temperature, No Action Cumulative Effects

Neither past or future vegetation management are expected to cumulatively contribute much to water temperature due to the location of these activities on slopes away from stream channels. On-going grazing management has the potential to cumulatively impact water temperature if shade species such as willow are grazed. However, standards and guidelines for grazing limit cattle use of willow, which are not preferred by cattle for forage unless other forage is not available. Under this alternative, grazing is likely to continue to concentrate along the streambanks where shade species grow, thus slowing the growth of shade species to some extent, resulting in no change in the current trend in water temperatures.

Streamflow, No Action Direct and Indirect Effects

The No Action alternative does not generate direct effects. The existing incised channel would continue to act as an early season drain for groundwater in the meadow. However, since a recent study has found that this effect diminishes significantly by mid-summer (USDA 2015), baseflows are not expected to be measurably higher during the low flow season.

Streamflow, No Action Cumulative Effects

Several recent studies indicate that any difference in stream flow timing and magnitude between the Proposed Action and No Action Alternative would be small and immeasurable at a regional scale that might affect downstream water uses in Red Clover Creek. Cattle would continue to concentrate along the stream channel under the No Action Alternative. However, with current SNFPA ROD standards and guidelines, they are less likely to affect stream flow through bank alteration leading to channel incision.

Floodplain Function, No Action Direct and Indirect Effects

Direct effects are not generated by the No Action Alternative. The stream would remain over eight feet below the historic floodplain under this alternative, rendering floodplain access impossible except under extreme conditions. Functional processes and riparian habitat vegetation would continue in a declining trend under this alternative. Advancing headcuts would continue to expand the separation of the channel from the floodplain, leading to further erosion until an adequate floodplain area is reached at the degraded gully elevation. The meadow would further its development as a terrace feature dominated by xeric plant species. There would be a further loss of soil at the site, and deposition of soil and silt in downstream reaches.

Floodplain Function, No Action Cumulative Effects

Vegetation management in the analysis watershed is not expected to to affect floodplain function under the No Action Alternative or the Proposed Action. Grazing impacts in floodplain function are likely to be more pronounced under the No Action Alternative because grazed plants cannot recover as quickly under the existing dry conditions as they would under the restored condition. Without vegetative cover, the floodplain would continue to erode.

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